RESNET 2014 February 24-26, 2014

Beyond Mini-Splits

An Introduction to Variable Capacity Equipment for Whole-House HVAC Designs

Allison Bailes, *Energy Vanguard*

Kristof Irwin, *Positive Energy*

Agenda

Preview
Perspective
Part-Load
VRF

Disclaimer

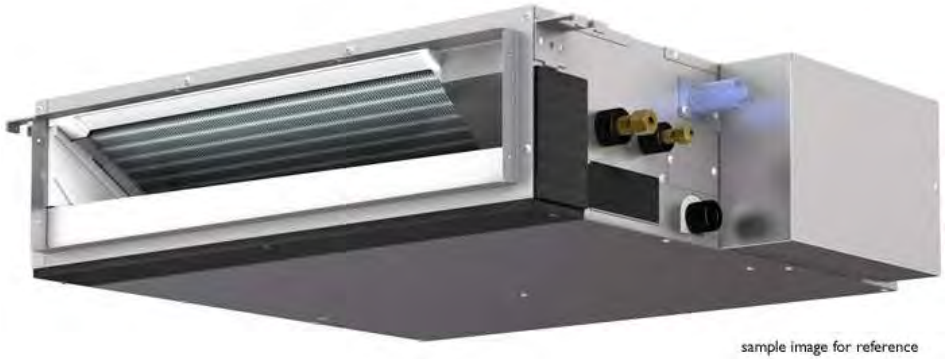
The mention of any product, service or information does not constitute an endorsement, nor implied endorsement. None of these companies are supporting this seminar.

What is VRF?

- Established heating & cooling technology for commercial and residential applications.
- Provides for variable capacity operation.

VRF Multi-Split Technology

VRF Multi-Split Technology



sample image for reference

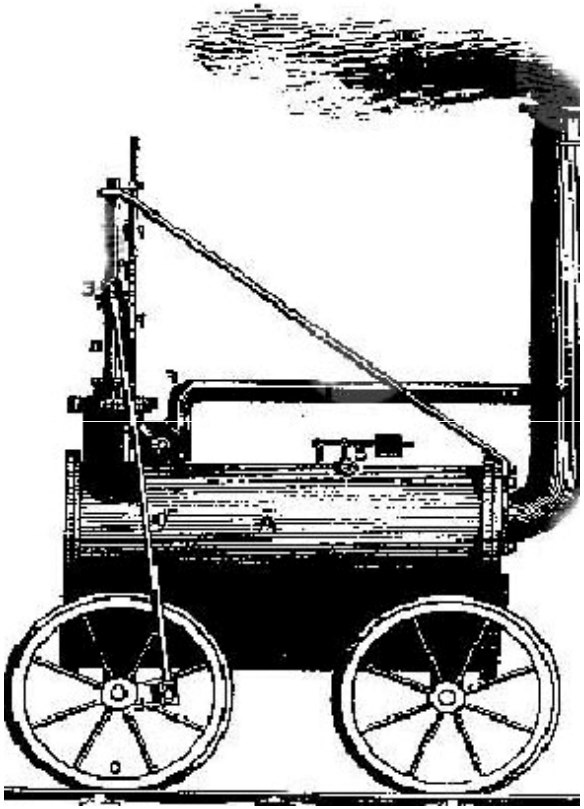
VRF Multi-Split Technology

VRF Vendors & Industry Dynamism

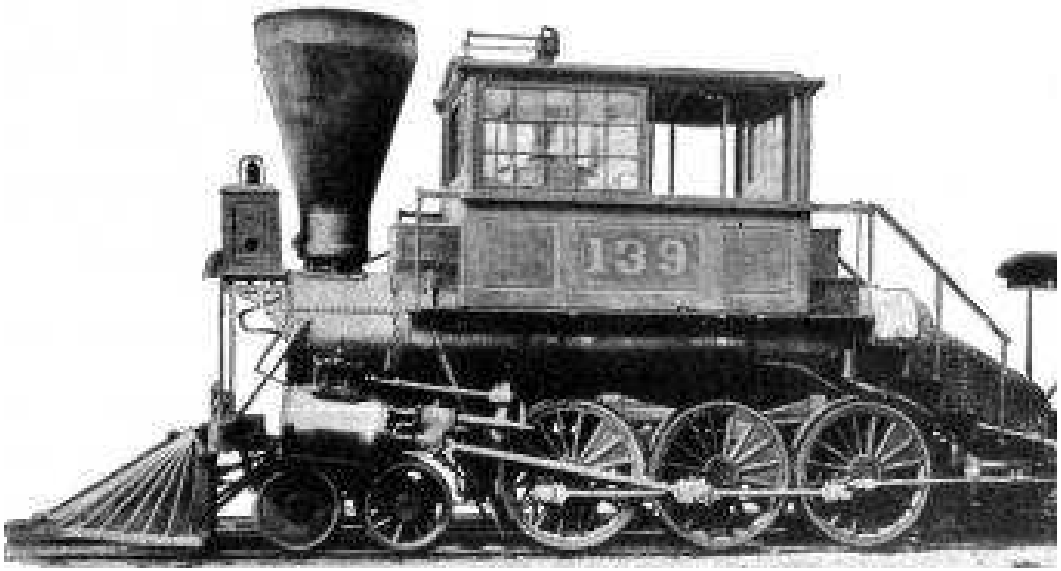
VRF Market Penetration

Perspective

50 Years



1803



1853

50 Years

1903

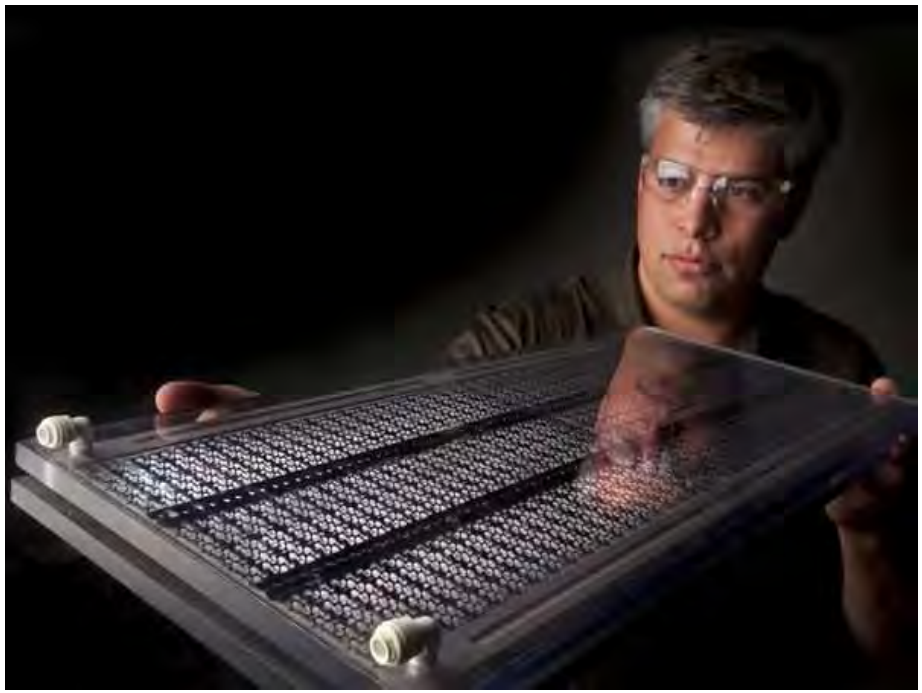
1953

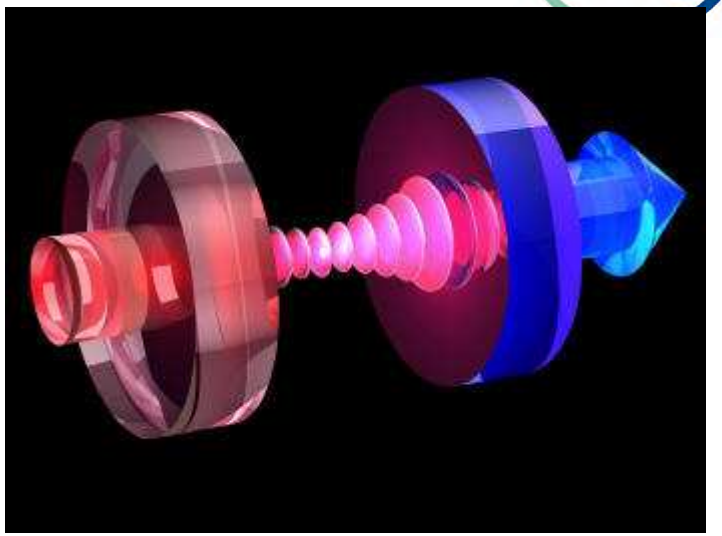
50 Years

1955

2055

HVAC Looking Forward…





- Desiccant based evaporative cooling (Especially Liquid Desiccants)
- Thermo-electric heating and cooling
- Quantum Effect devices

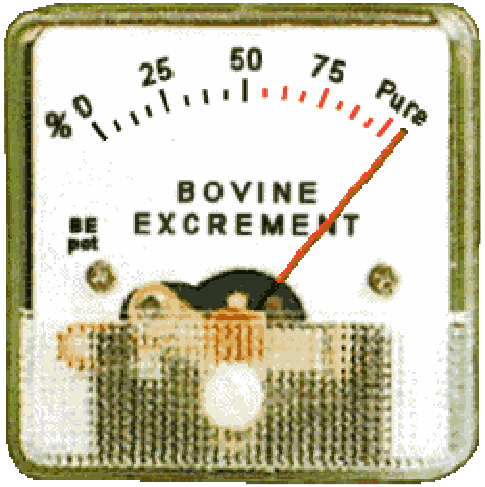
Changing Performance

Enhanced functionality. Superior performance.

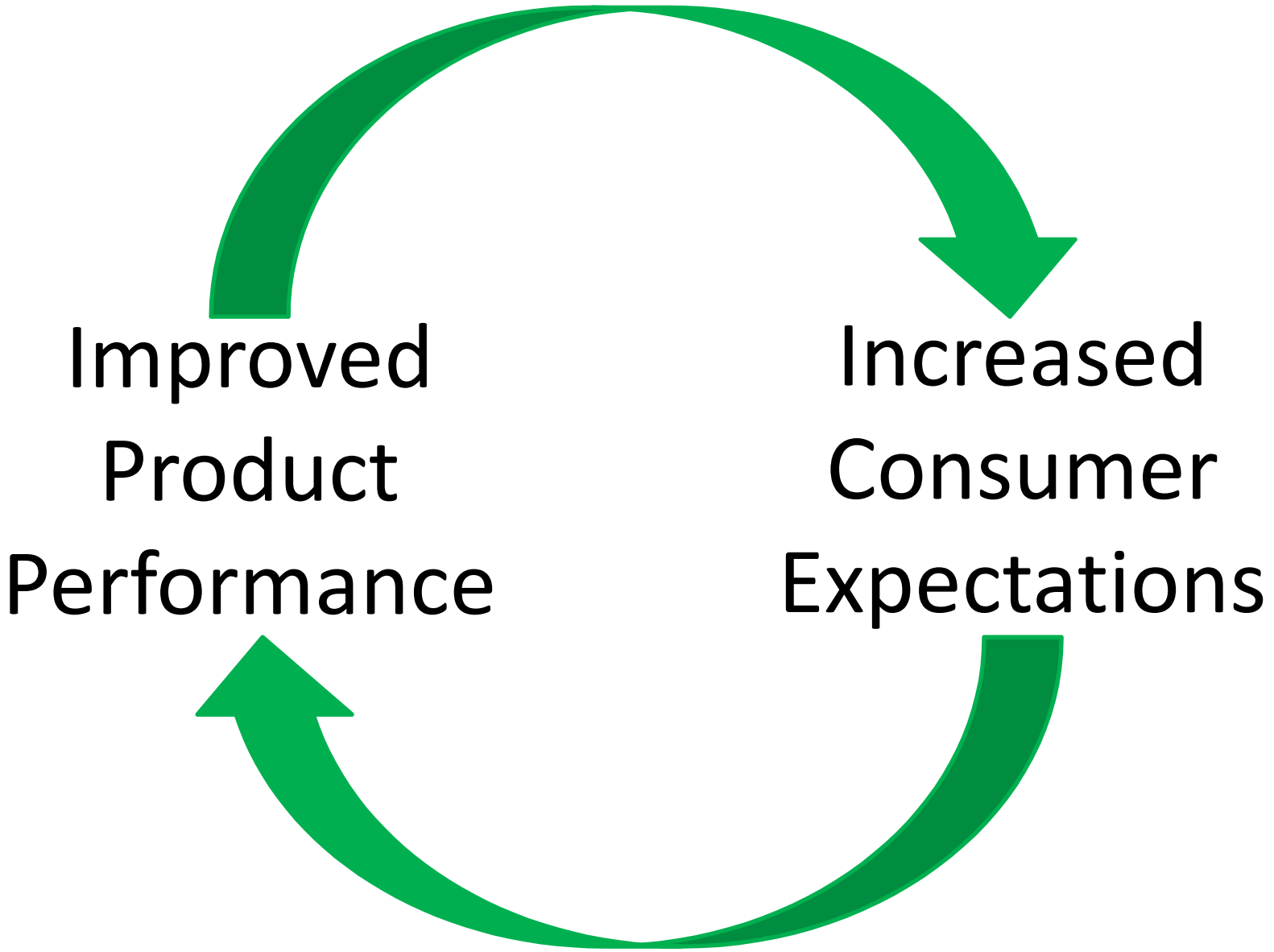
Not for free

- Highly engineered systems
- Specialized materials
- Complex assemblies
- Precise tolerances

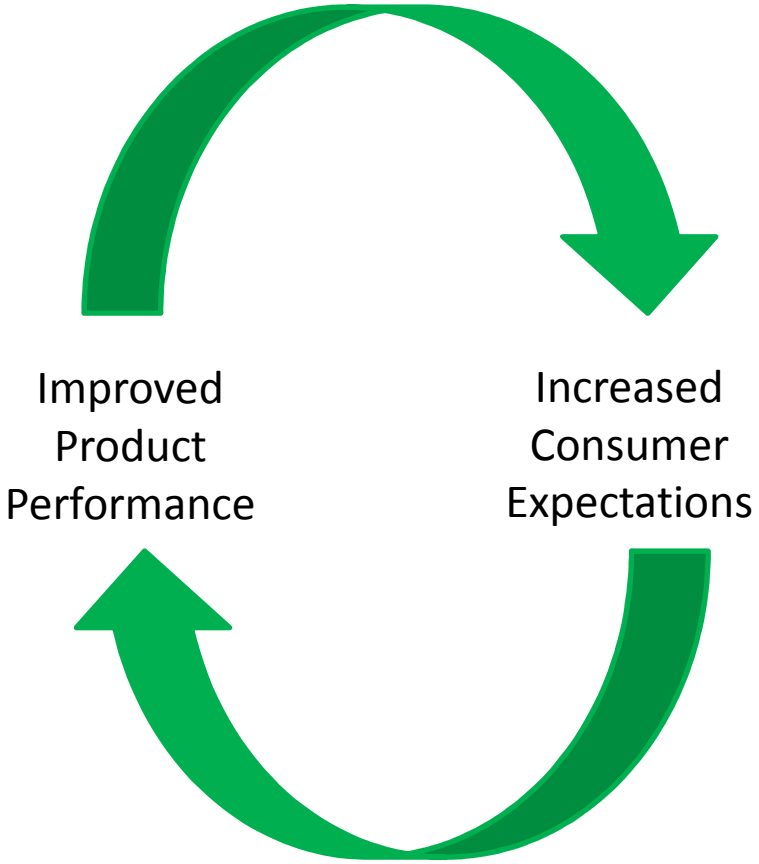
Changing Client Dynamics



Feedback Loop



The New Normal



High Performance

- Comfort
- Health
- Safety
- Durability
- Energy Efficiency

Control Layers & Equipment Loads

One Functional System

What do we want this system to do?

What should it deliver?

- Comfort
- Durability
- Health
- Safety
- Energy Efficiency

+

Control Strategy

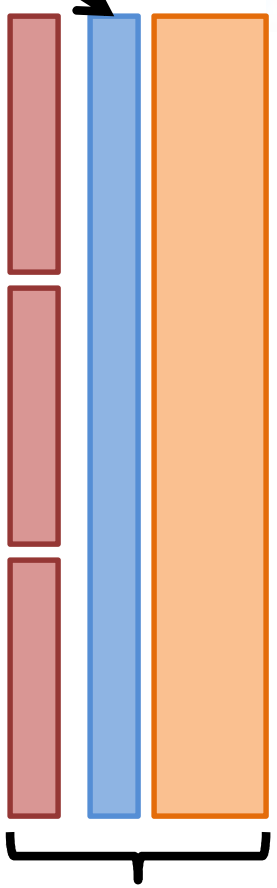
Control flows across a boundary:

- Heat
- Air
- Moisture

Control Layers

Priority Order:

1. Bulk Water
   (Rain & Ground, Liquid)
1. Air
2. Water Vapor
3. Thermal



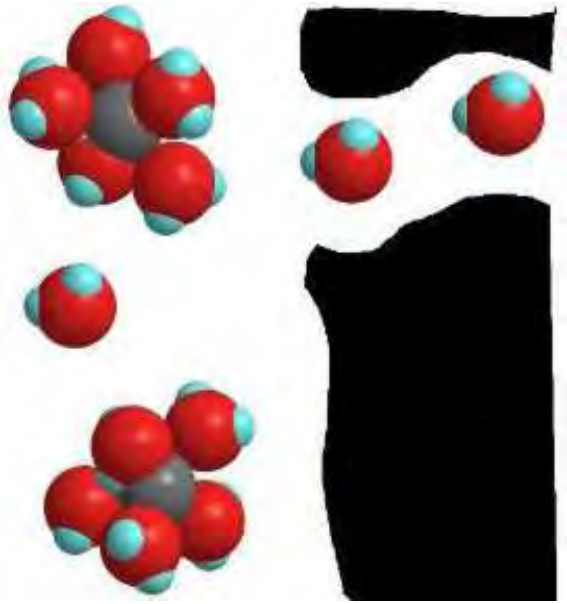
Building Envelope
Assembly (Boundary)

Control Layer Failure

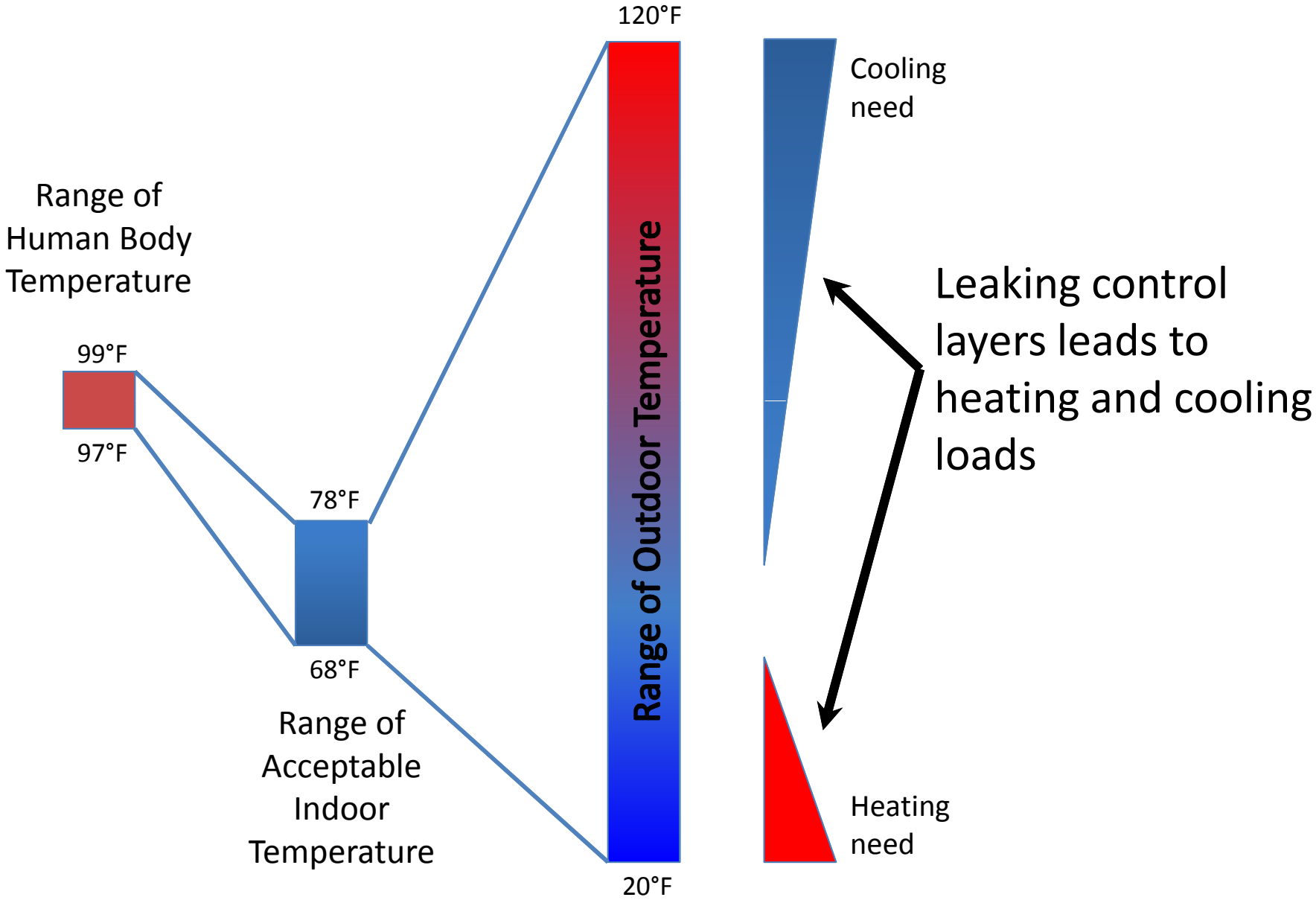
Keep Outside Out & Inside In. Control Exchange.

Control layer failure - All 3 Required

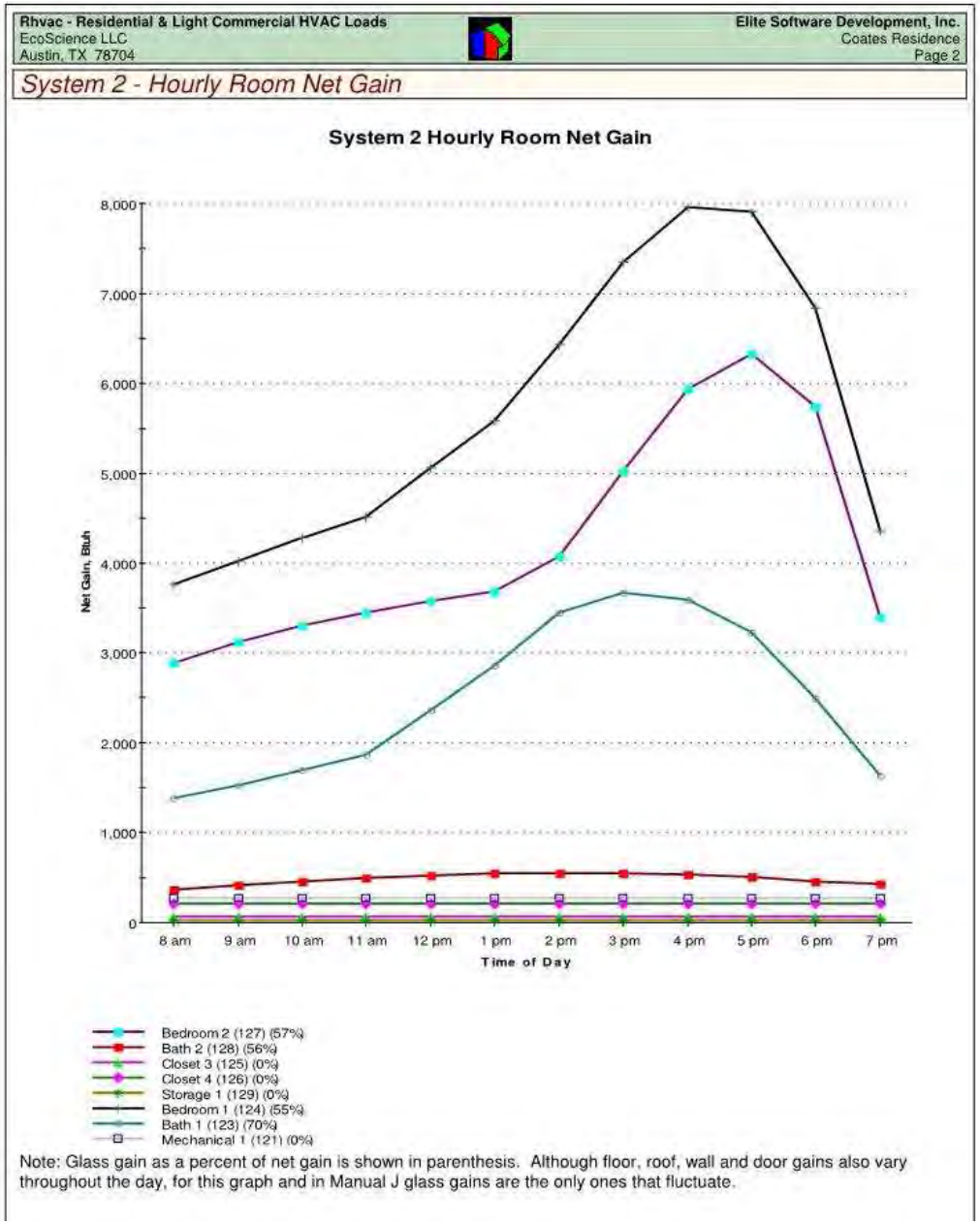
1. Something to leak
2. Opening
3. Driving force



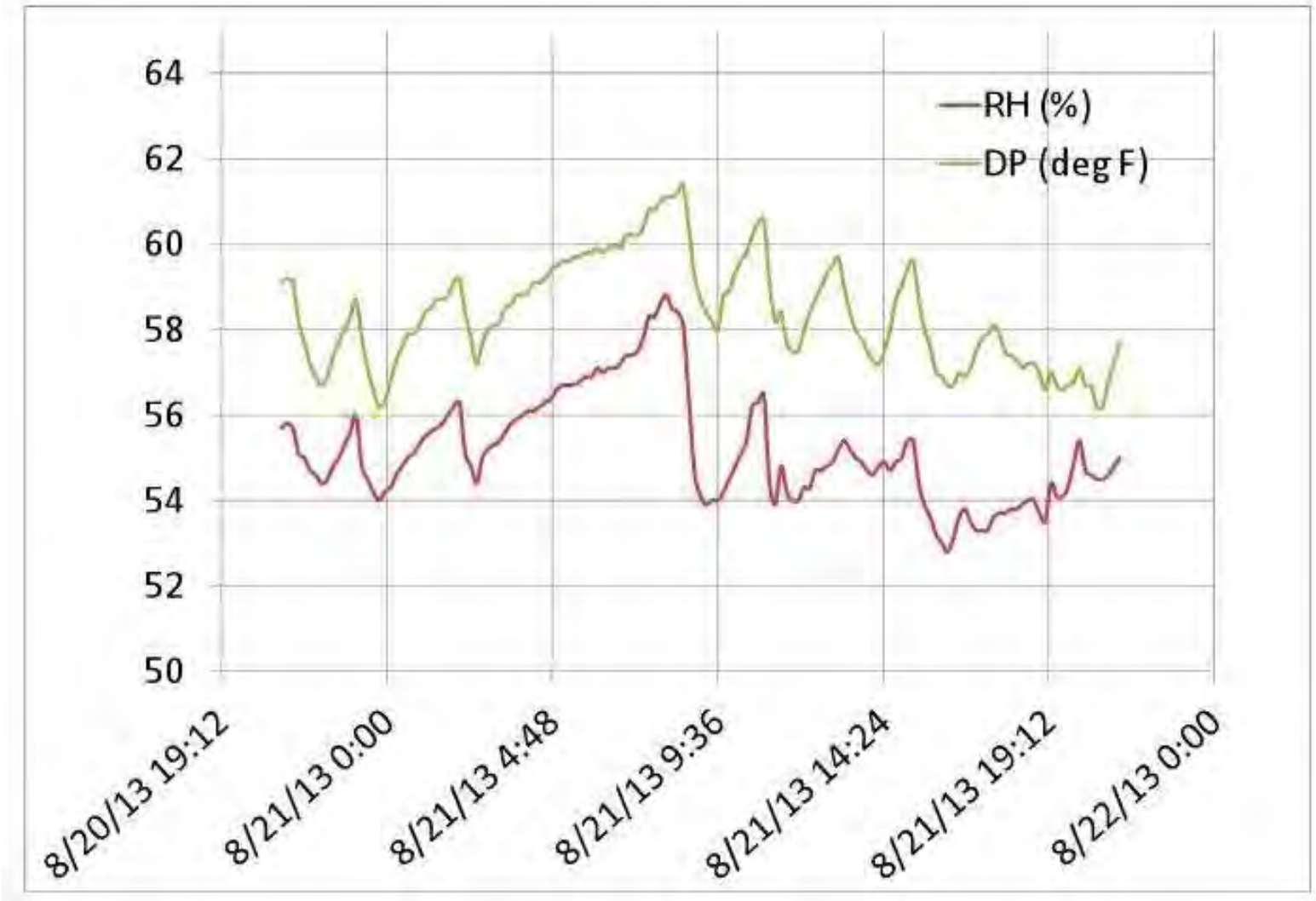
Control Layers are Imperfect



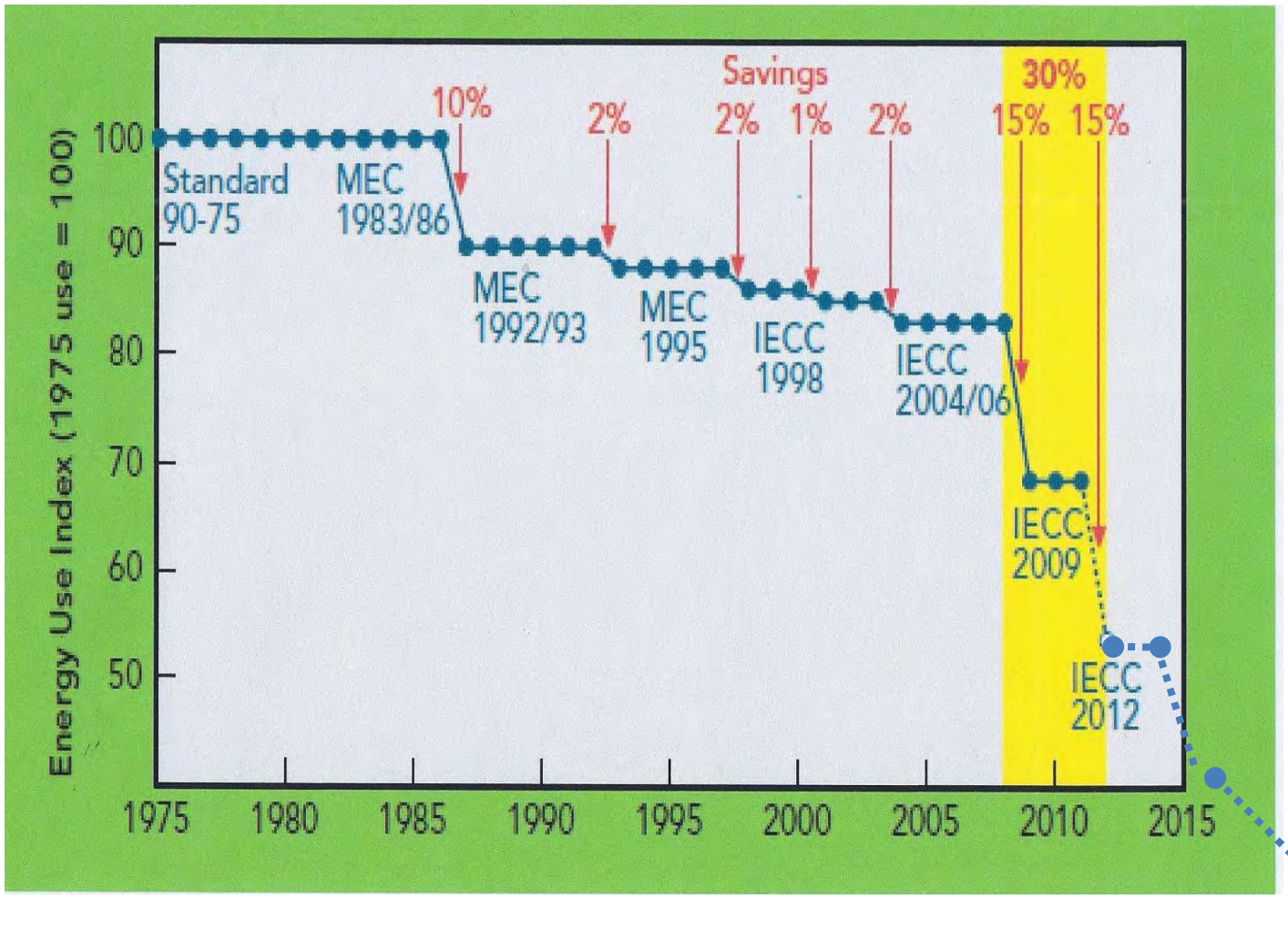
Daily, Hourly Load Variations



Typical Indoor Weather Pattern



Changing Energy Codes



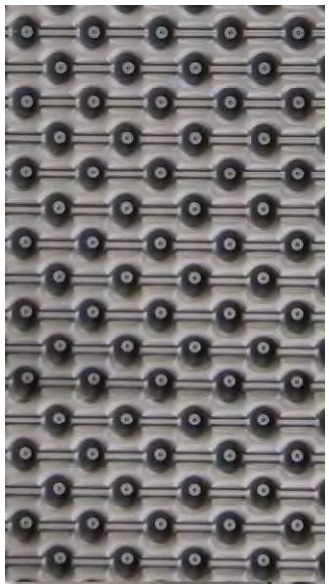
Moisture tolerance and resiliency following similar trend?

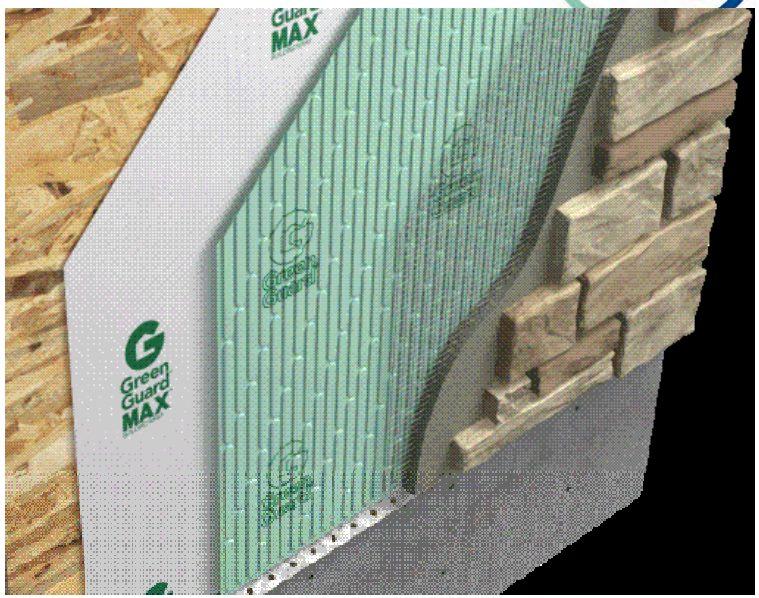
Changing Building Envelopes

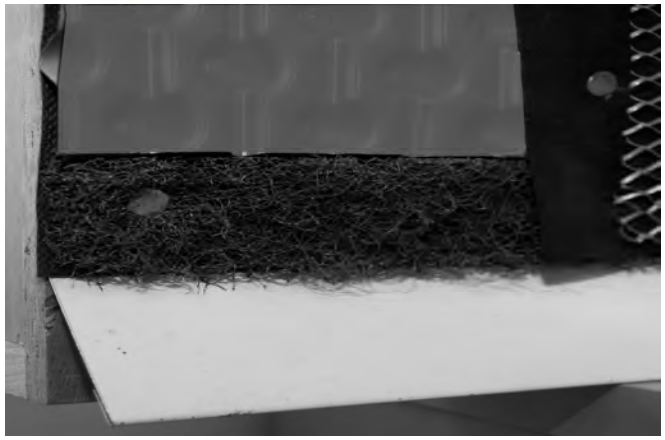
Control Layer Products

There's something happening here

What it is, is very clear







Control & Kaos?

Load & Part Load

Fixed Capacity & Variable Capacity

Load & Capacity

Load

Capacity

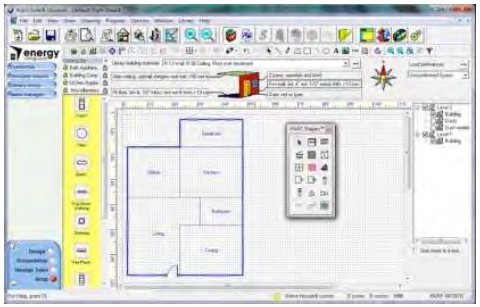
3 Types of People

1. Those who can do math
2. and those who can’t.

3 Types of Loads

Extreme Load

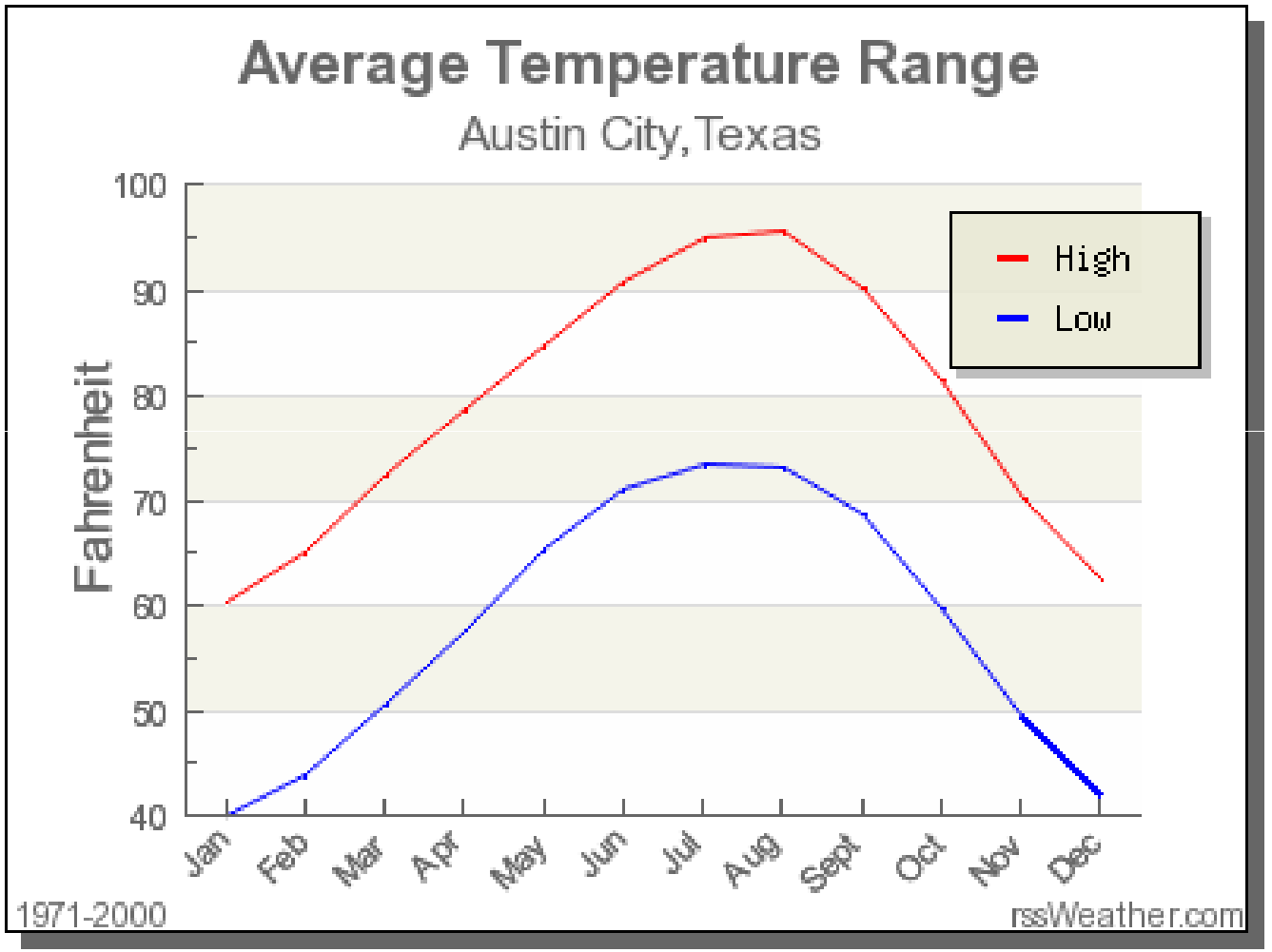
Design Load

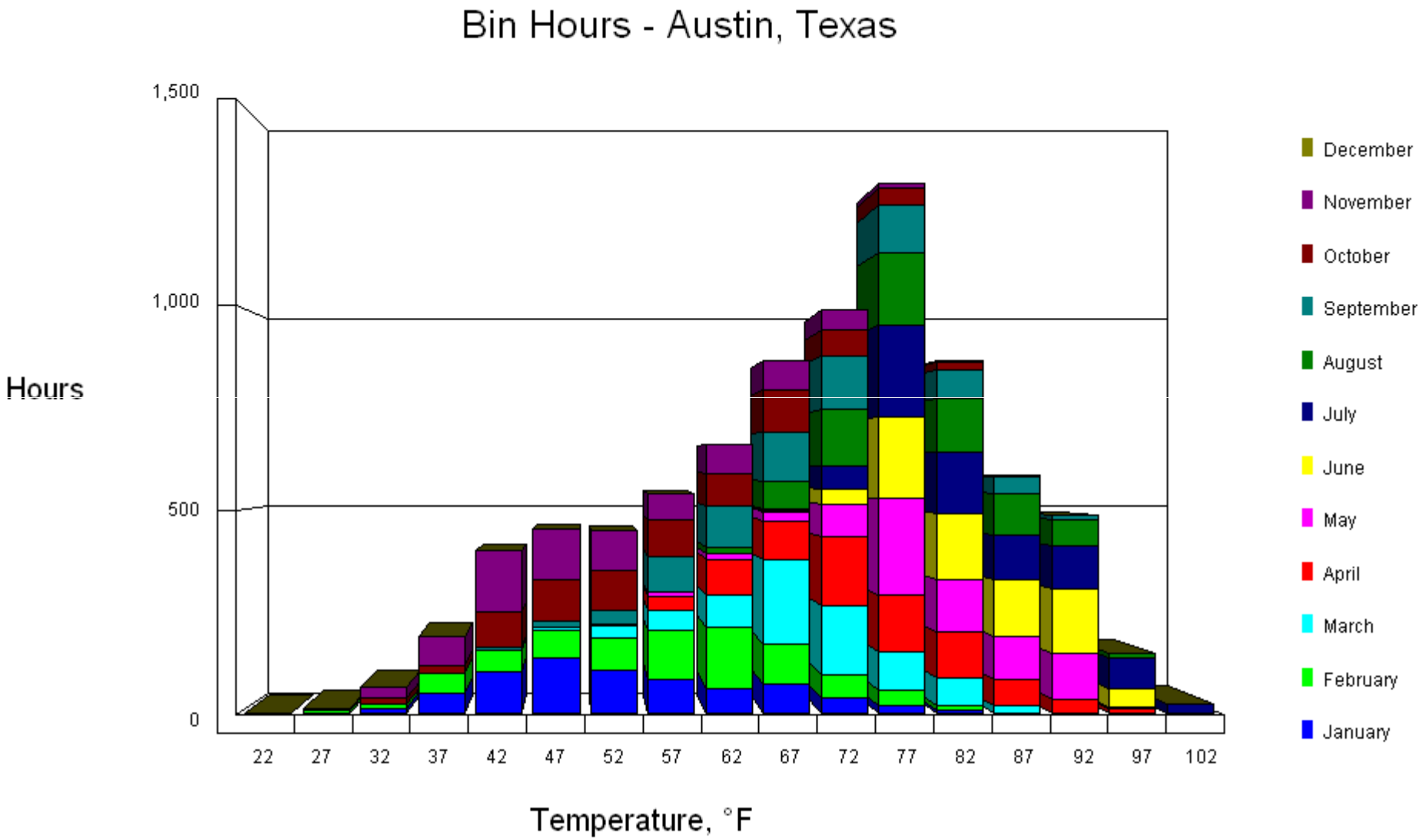


Part Load

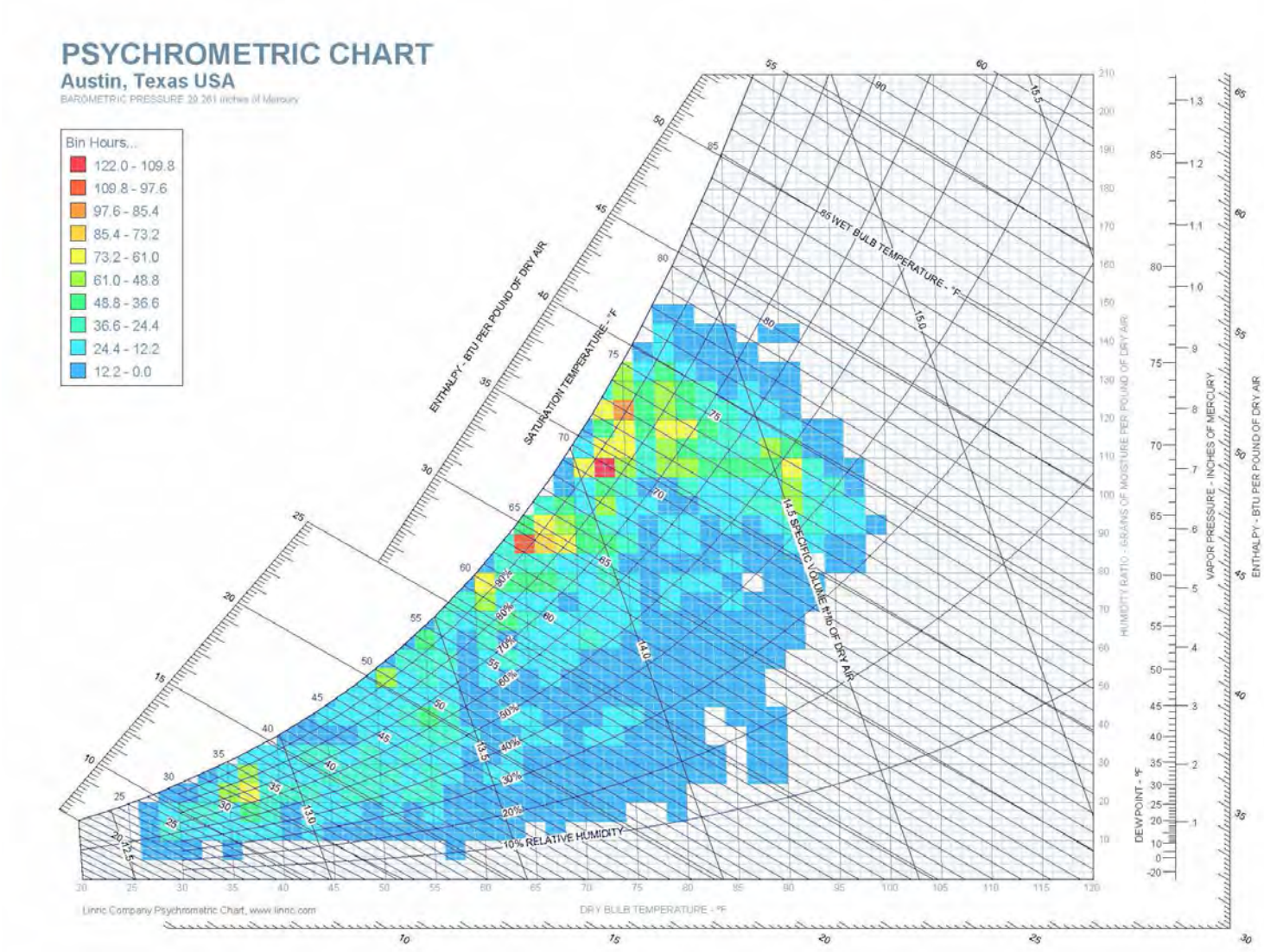
Variable Loads

Austin Climate

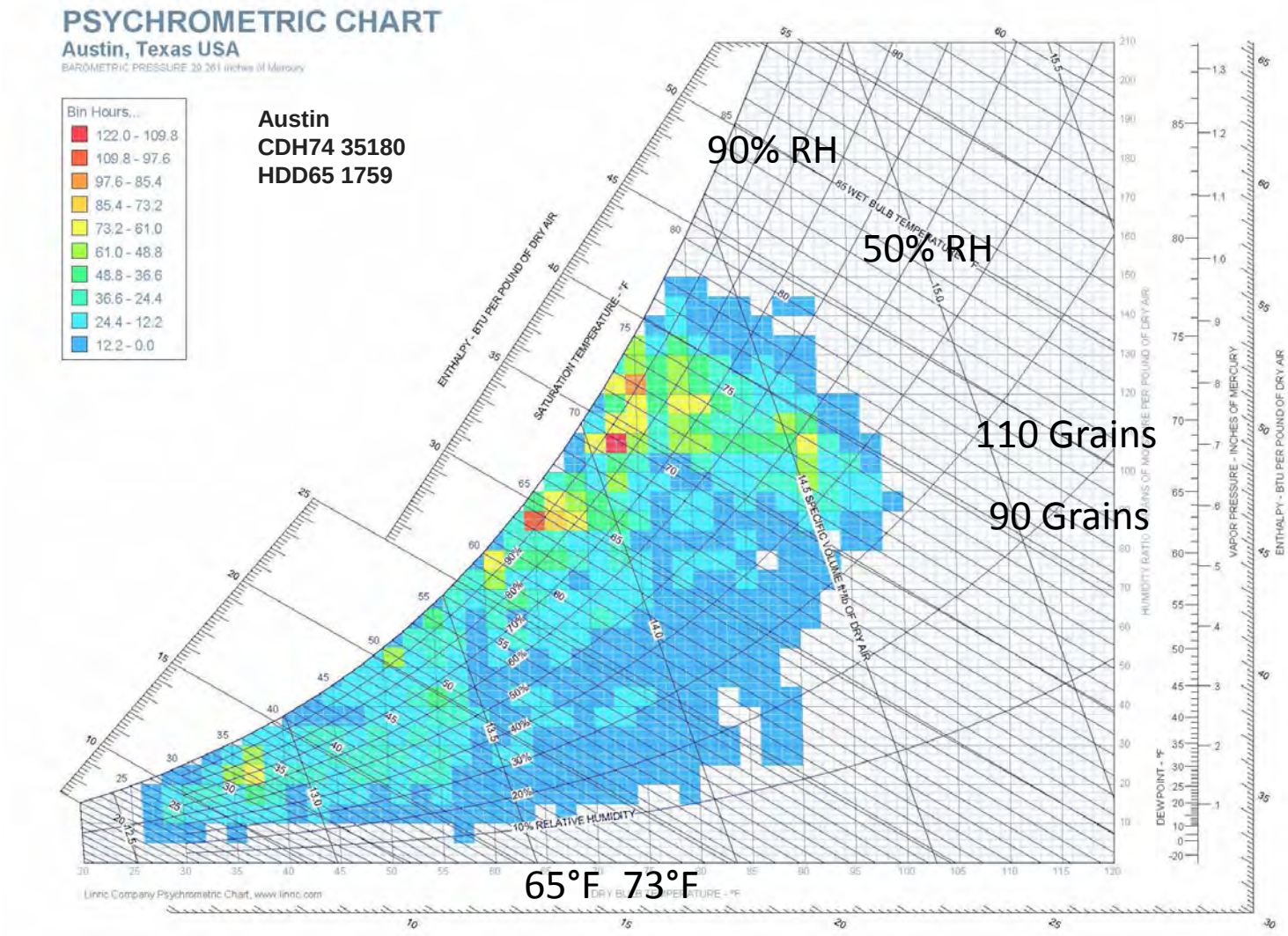



Bin Hours - Austin, Texas
Hours
1,500
1,000
500
0
22
27
32
37
42
47
52
57
62
67
72
77
82
87
92
97
102
Temperature, °F
December
November
October
September
August
July
June
May
April
March
February
January

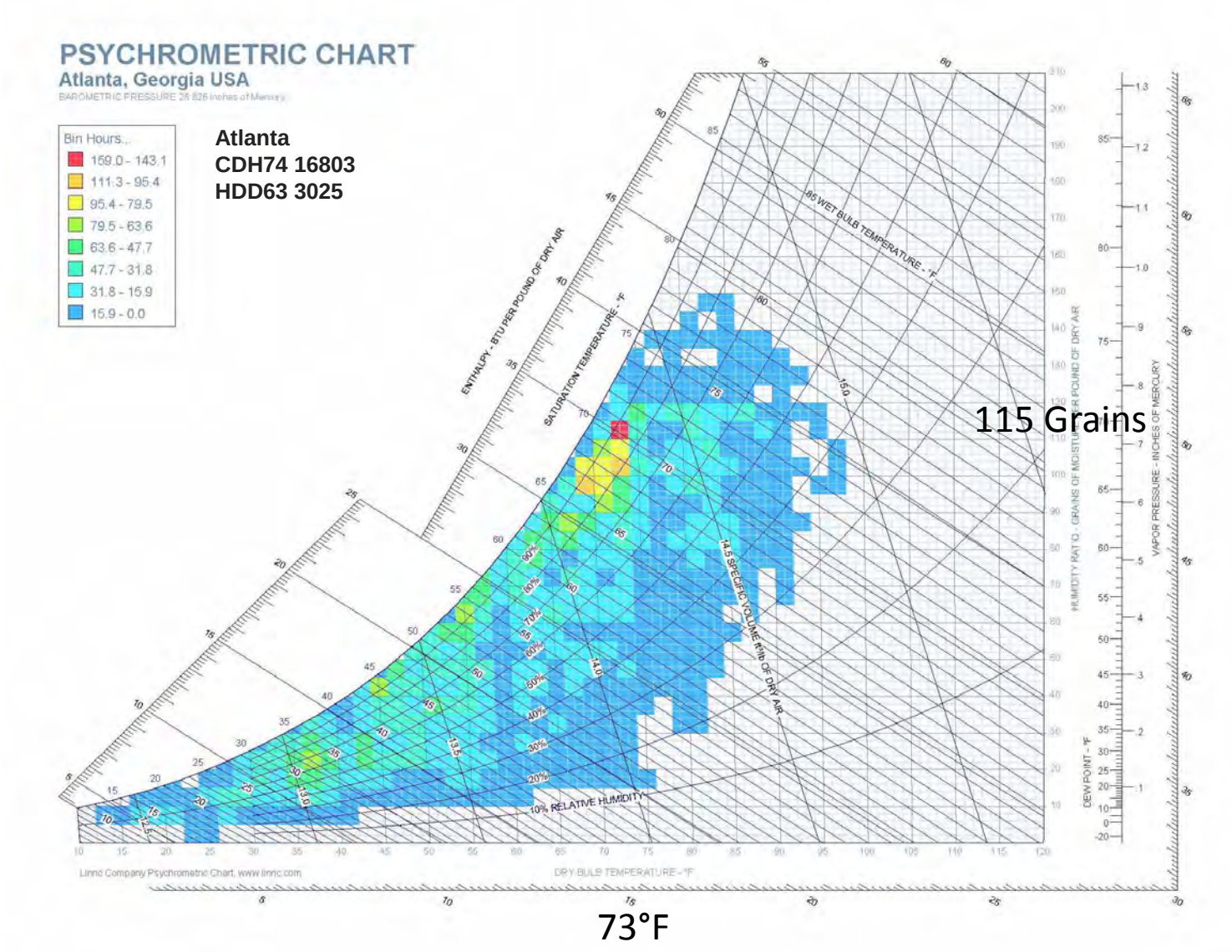
Austin Climate



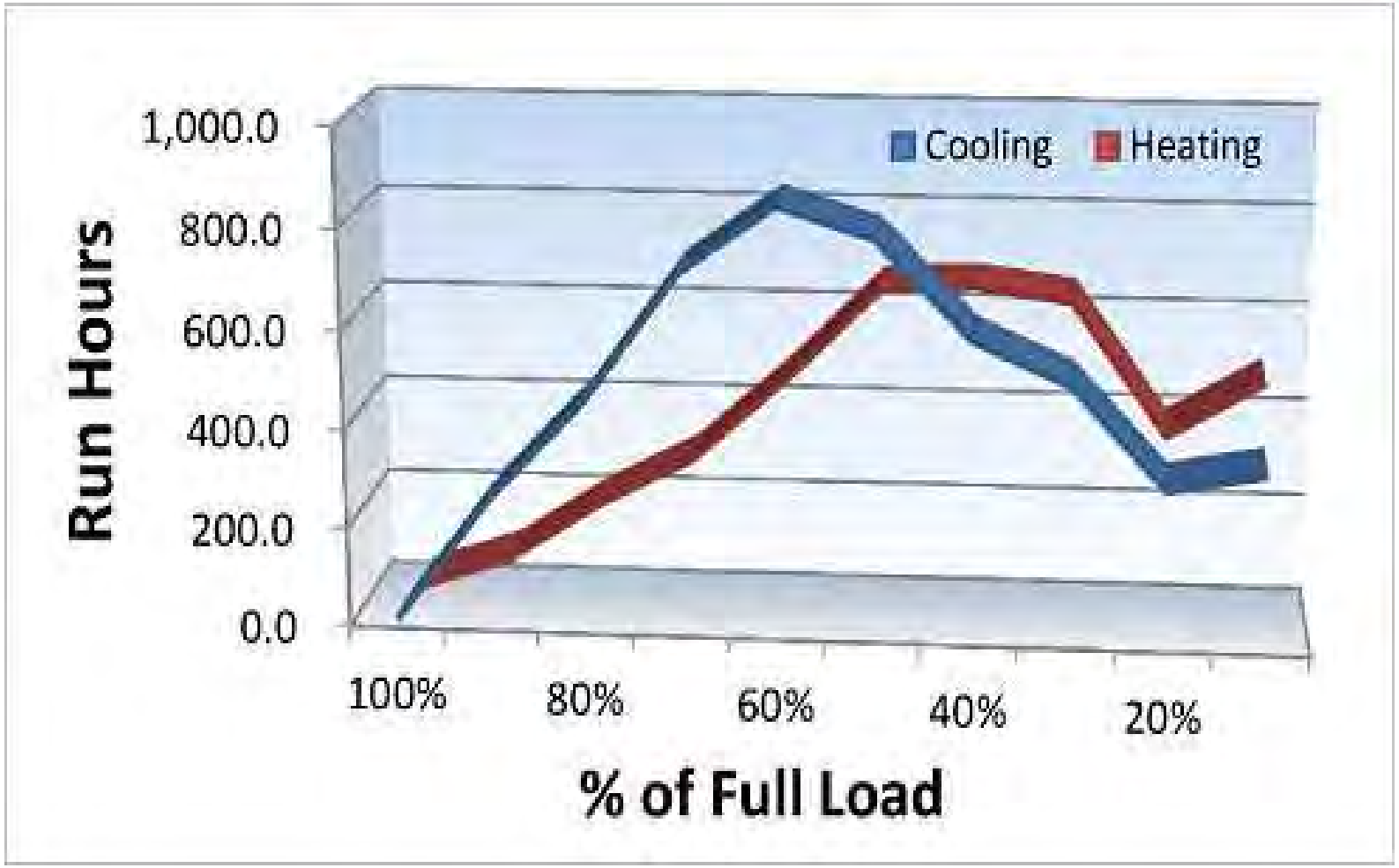
Austin Climate



Atlanta Climate

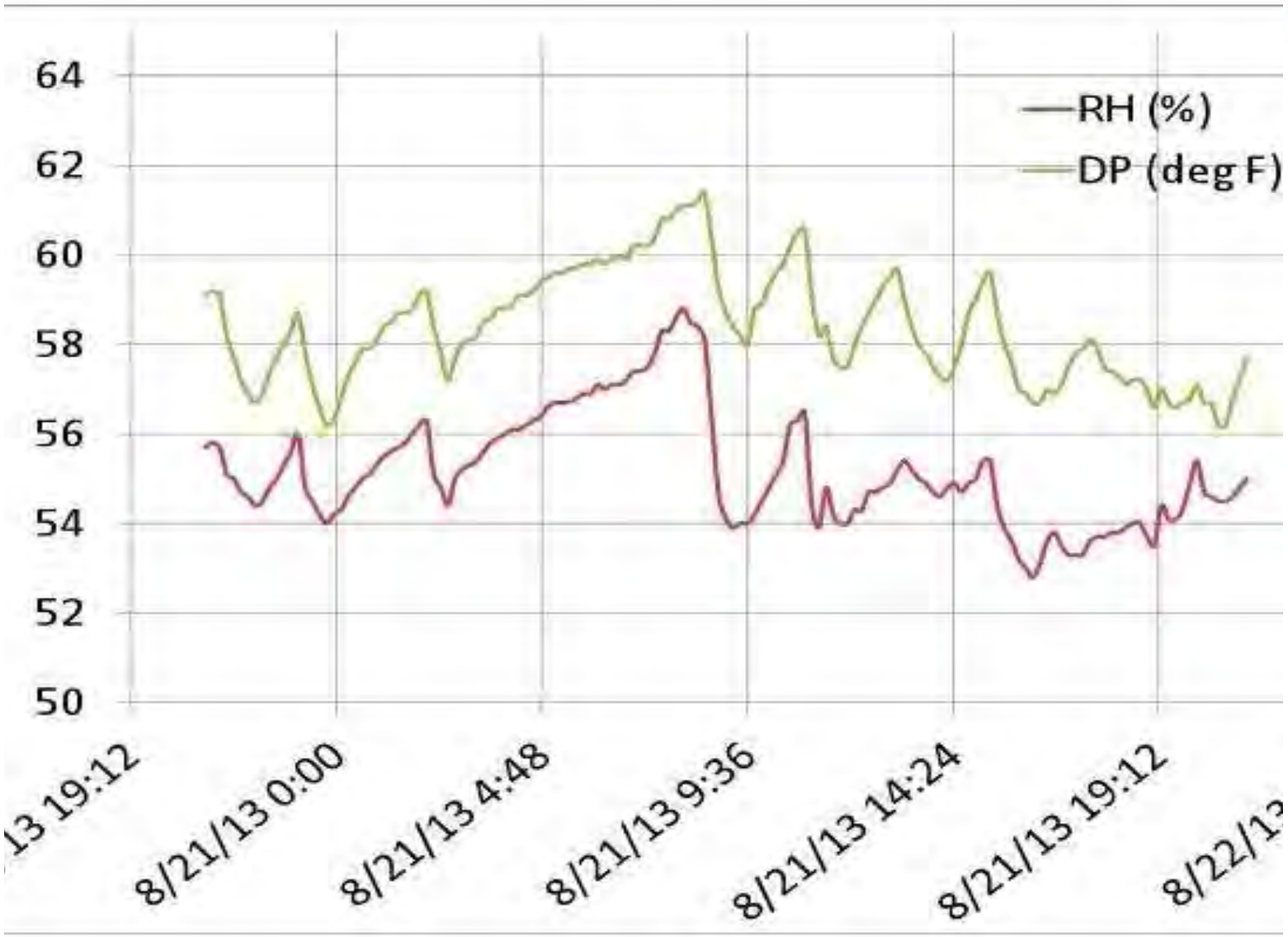


Part Load Hours



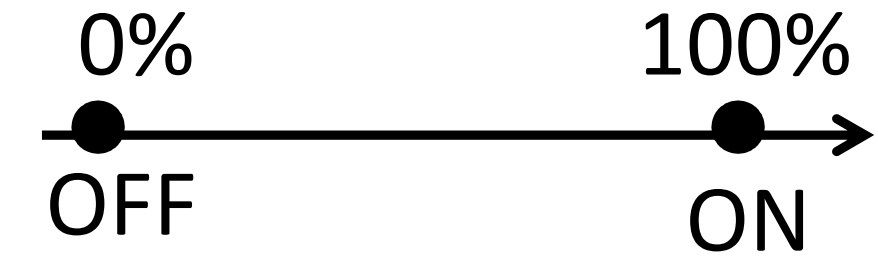
Source: HTS Engineering

No Cooling. No Dehu.



Fixed Capacity

Single Speed

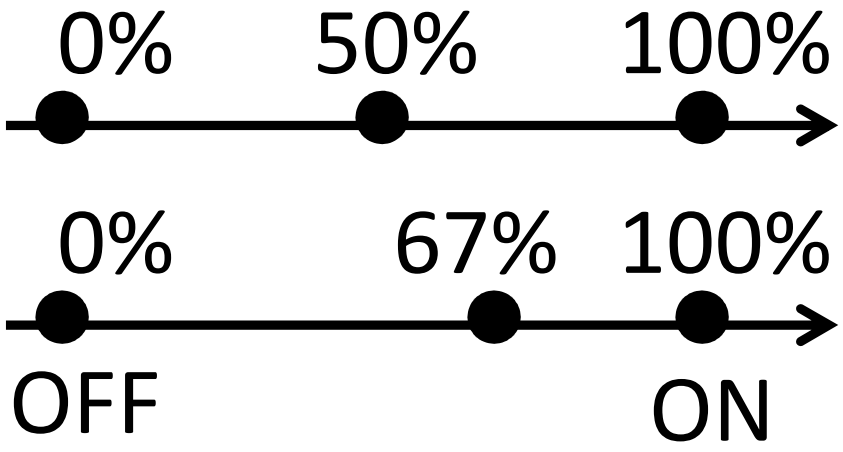


- Dot represents Equipment Operating Point & Percentage of Rated Capacity Delivered to Load (idealized)

Majority of US Market

Dual Capacity

Dual Stage & Unloaders



Variable Capacity

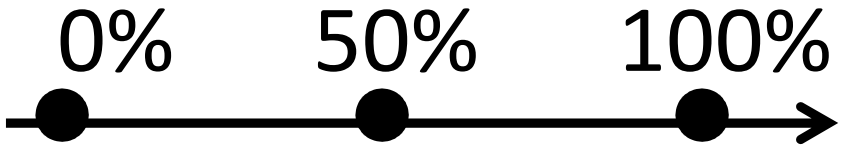
Inverter Scroll Compressor

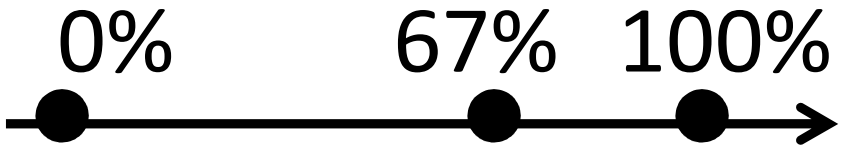
0% 4-15% 100%

3 Types of Capacity

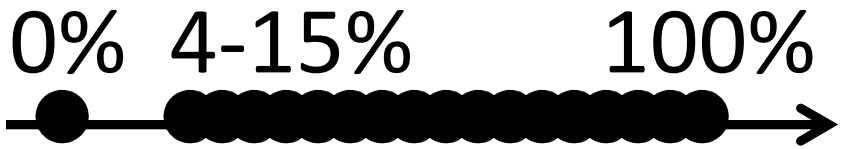
Single Speed

Dual Stage & Unloaders





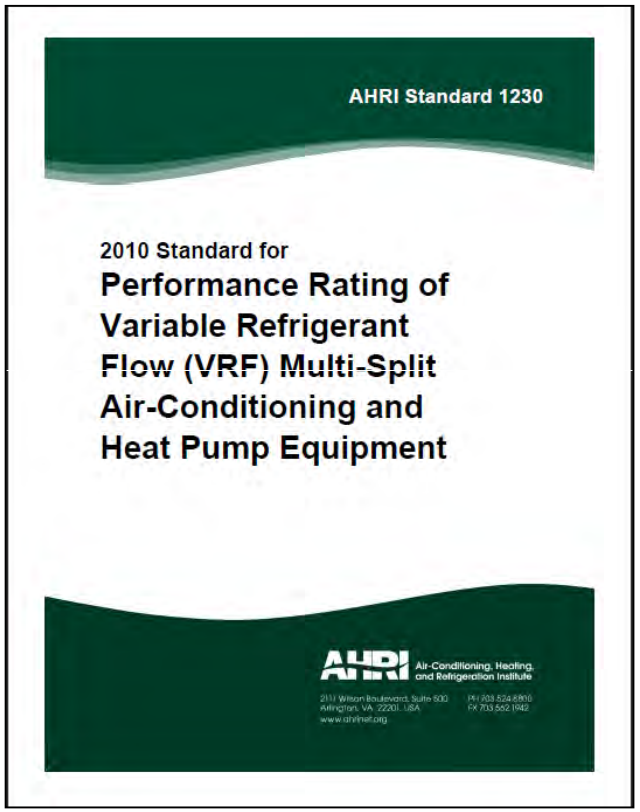
Variable Capacity



VRF & Industry Performance Metrics

AHRI 1230-2010

- Full Load
  - EER
  - COP @47F
  - COP @17F
- Part Load
  - IEER
- Heat Recovery
  - SCHE



Performance Metrics

Rated at Full Capacity Conditions

- **EER** – Energy Efficiency Rating = Btuh's per Watt
- **SEER** –**S**easonally adjusted; per AHRI formula
- **HSPF** – Heating Seasonal Performance Factor
- **COP** – Coefficiency of Performance = In North America, typically rated for Heat Pumps at 17 & 47 degrees Fahrenheit.

Performance Metrics

Rated at Part-Load capacities (25%, 50%, 75% & 100%)

- **IEER** – Integrated Energy Efficiency Rating; Took the place of IPLV

- **SCHE** – Simultaneous Cooling & Heating Efficiency

  Efficiency of Heat Recovery at simultaneous 50% heating & 50% cooling

IEER

$$IEER = (0.020 \cdot A) + (0.617 \cdot B) + (0.238 \cdot C) + (0.125 \cdot D)$$

Where:

A = EER at 100% net capacity at AHRI standard rating conditions

B = EER at 75% net capacity and reduced ambient (see Table 11)

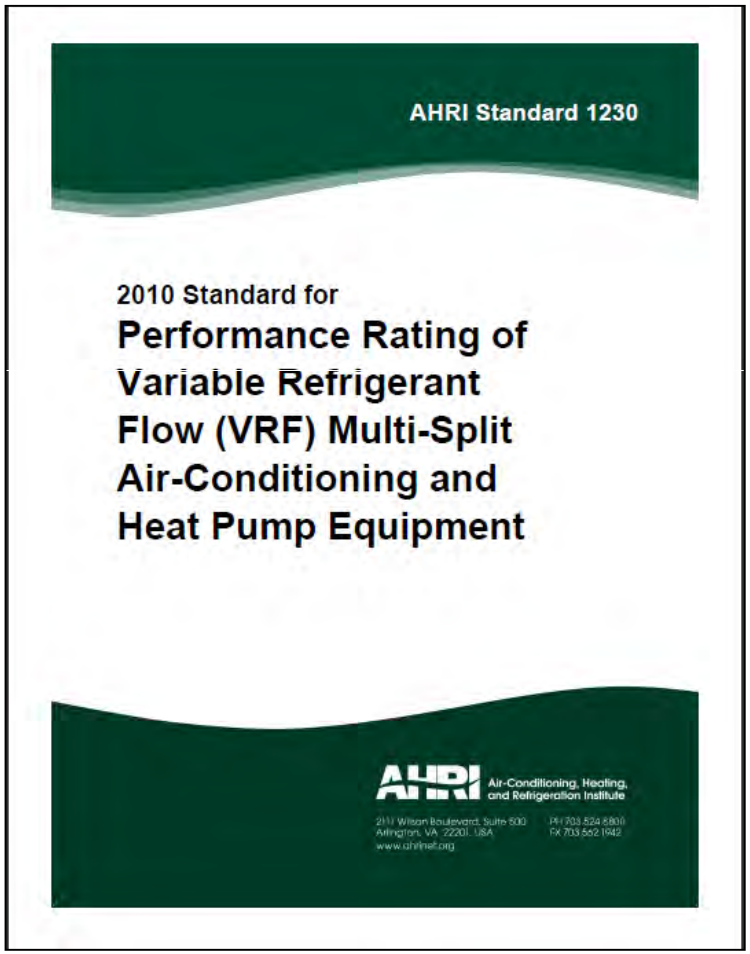
C = EER at 50% net capacity and reduced ambient (see Table 11)

D = EER at 25% net capacity and reduced ambient (see Table 11)

(IPLV@0.1,0.5,0.3,0.1)

> 65kBtuh Only

Part load metrics only apply to equipment with capacities > 65kBtuh



VRF HVAC Technologies

VRF Technology

VRF Technology

Outdoor Condensing Units

S-Series
3-5 Tons
1Φ
14x38x54

R2, Y, H2iY
6-24 (30) Tons
3 Φ
30x48x65

WR2, WY,
6-24 (30) Tons
3 Φ
21x34x43

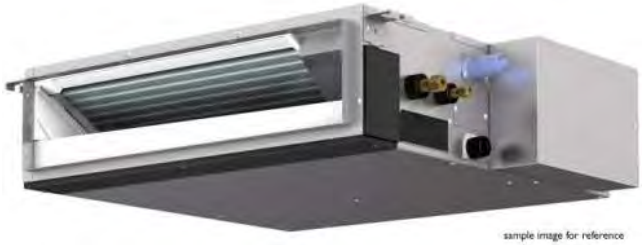
VRF Outdoor Units

Manufacturer	Lennox		Mitsubishi
Model Number	XP25-036		PUMY-P36
Cooling Cap (kBtuh)	35.2		36
Heating Cap (kBtuh)	31		40
Pwr Htg (kW)			2.93
Pwr Clg (W)			3.22
Current Clg (A)	LRA 18, RLA 14		15.2
Current Htg (A)			12.9
Dims (WxDxH)	30x39x36 (48)		13x38x54
Weight (Lbs)			287
Sound P (dB(A))	58/73 (min/max)		49/51 (min/max)

Indoor Units

Space Mounted

Ceiling Recessed



Concealed Ducted

Space Mounted

Wall Mounted
6-30kBtuh

Ceiling Suspended
15-36kBtuh

Floor Standing
6-24kBtuh

Wall Units

Trane 4MYW6 9-22 kBtuh

Fujitsu Halcyon ASUxxRLF 7-24 kBtuh

Gree GWCxx 9-36 kBtuh

Floor Standing

LG ARNUxxxCE 7.5-24.2 kBtuh

Mitsubishi PFFY-PxxNEMU-E 6-24 kBtuh

Panasonic S-xxMR1U6 7-24 kBtuh

Floor Standing

sample image for reference

Image Source: Mitsubishi Electronics

Space Mounted: Choices

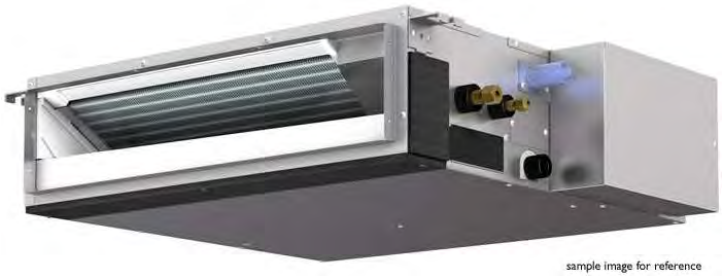
Ceiling Recessed

4-Way Large Cassette
33”x33”, 12-36kBtuh

4-Way Small Cassette
22.5”x22.5”, 12-36kBtuh

One Way Cassette
16”x32”, 6-15kBtuh

Concealed Ducted



Low (0.2iwc)
Medium (0.6iwc)
High Static (0.8iwc)

6 - 96kBtuh
(1/2 to 8 Tons)

VRF Multi-Split Air Handlers

Panasonic S-xxMM1U6 0.7-18 kBtuh

Daikin FXMQxxPVJU 0.6-4.0 kBtuh

Carrier/Toshiba MMD4 2.5-4.0 kBtuh

Vertical Ducted

Vertical (Up or Down Flow)
& Horizontal Left Air Handler
0.3, 0.5, 0.8 iwc, 12-54kBtuh

Vertical (Horizontal) Air Handlers

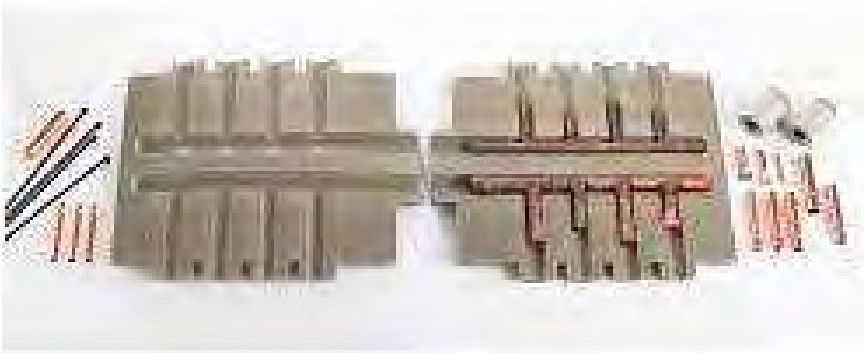
Manufacturer	LG	Mitsubishi	DAIKIN
Model Number	ARNU183NJA2	PVFY-P18E00A	FXMQ18PVJU
Cooling Cap (kBtuh)	18	18	18
Heating Cap (kBtuh)	20	20	20
Pwr Htg (W)	0.08	0.18	0.21
Pwr Clg (W)	0.08	0.18	0.21
Current Clg (A)	0.36	1.22	1.6
Current Htg (A)	0.36	1.22	1.6
Dims (WxDxH)	18 x 21.3 x 48.6	17-3/4 x 21 x 42-3/4	39-3/8 x 27-1/2 x 11-3/4
Weight (Lbs)	117	98	80
Sound P (dB(A))	39/41/42	35/35/36	37/41
CFM (L-M-H)	380/480/530	402/485/520	529/582/635
	0.3, 0.5	0.3, 0.5, 0.8	0.2, 0.8

Branch Boxes, Splitters & Joints

sample image for reference

VRF: Other Parts

Filter Chassis



Piping Headers & Joints

PC Connection

Concealed Ducted

Concealed Ducted

Concealed Ducted

VRF and Existing Buildings

- Less intrusive to existing architecture
- Small refrigerant piping instead of large ductwork
- Outdoor installation flexibility

How?

Variable Refrigerant Flow

Variable Refrigerant Flow

Linear Electronic Expansion Valve (LEV)

- LEV opens & closes a precise amount w/ each control pulse to its windings
- Thousands of pulses per full open/close
- Precision microprocessor based control

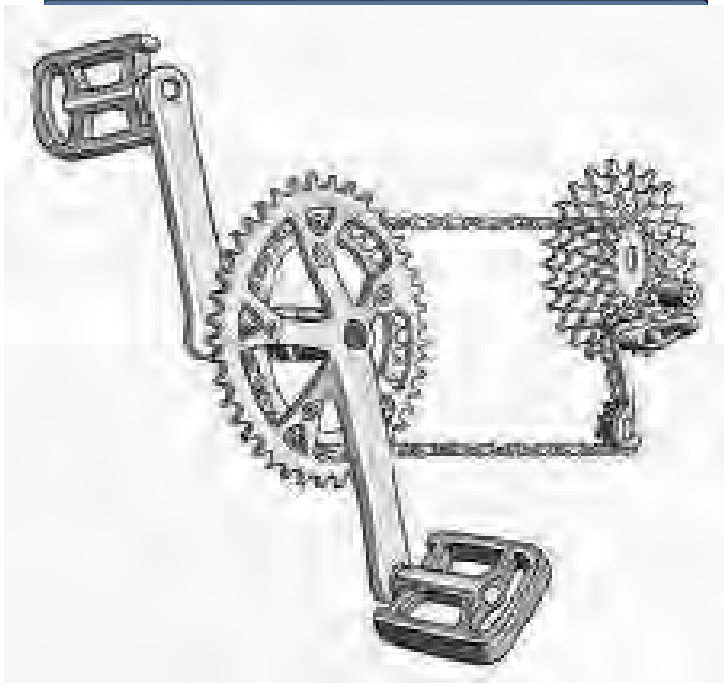
Variable Refrigerant Flow

Inverter Drive

60Hz VAC In

→

Inverter Circuit:
Variable Frequency & Voltage Output



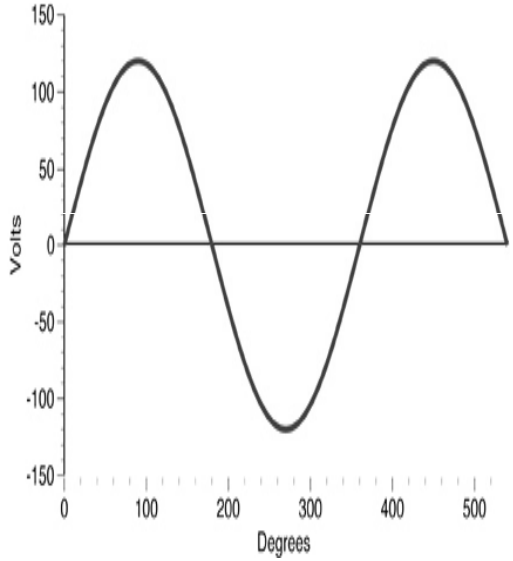
→

Variable Capacity

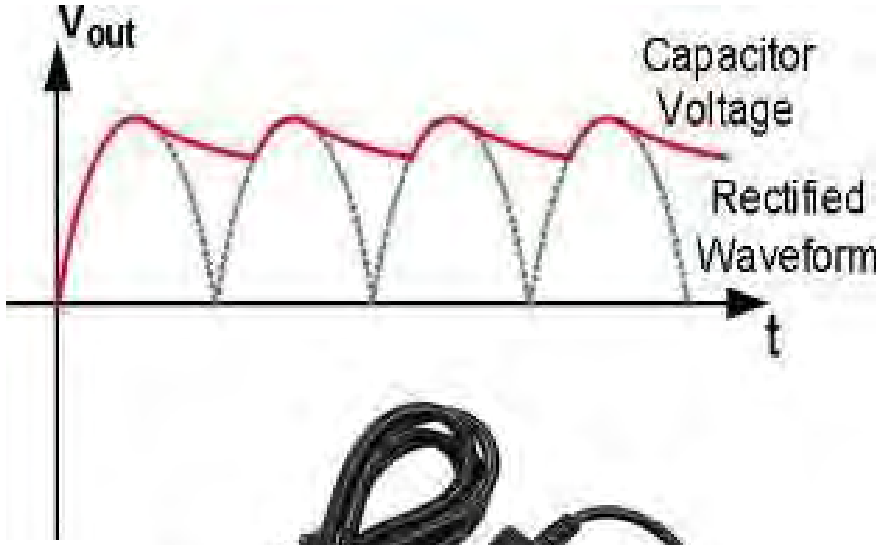
15 – 125 Hz VAC Out

Inverter Circuit: Step 1

AC → DC



→



Inverter Circuit: Step 2

DC → AC

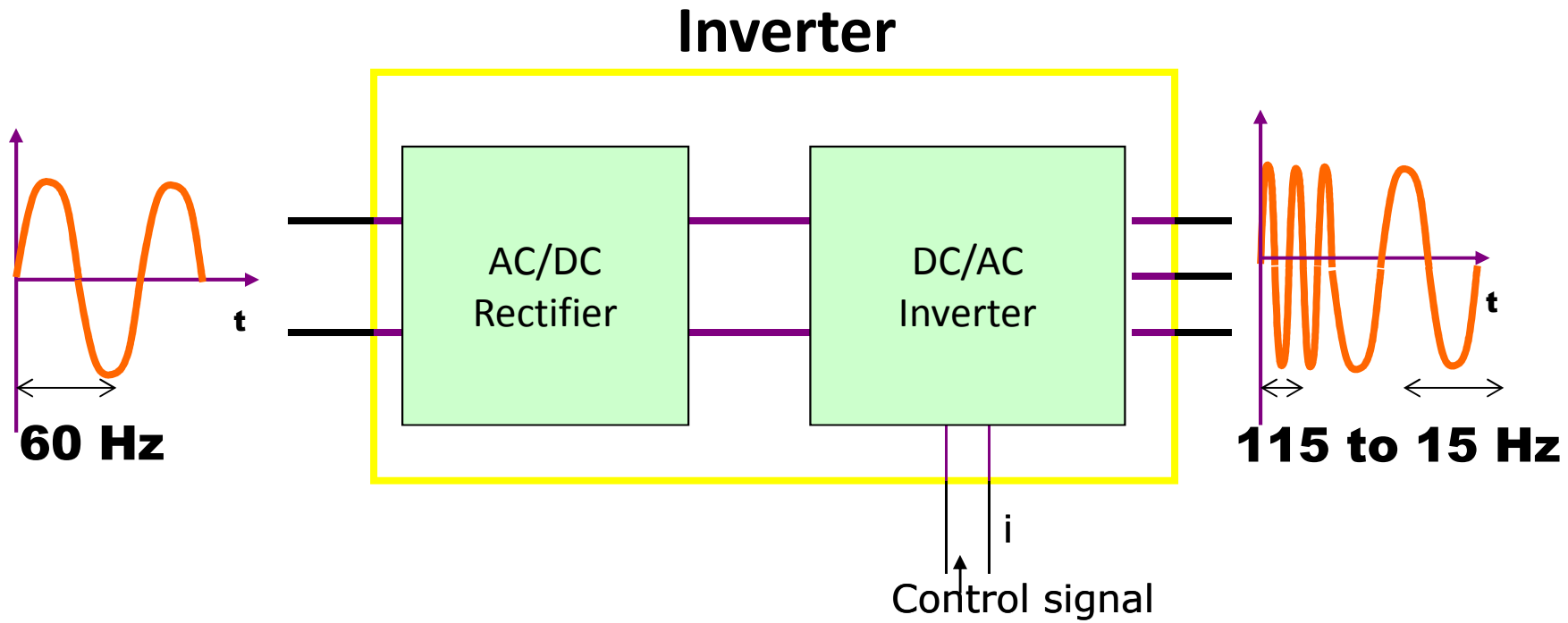
Fronius

POWERING YOUR FUTURE

DC to AC on Demand

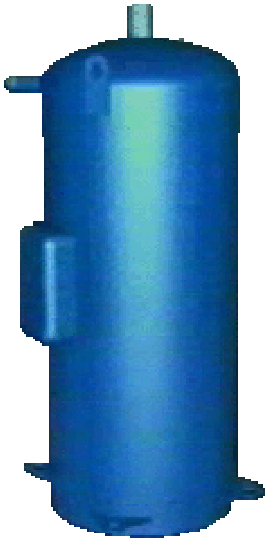
Fixed Input Power Frequency 60Hz

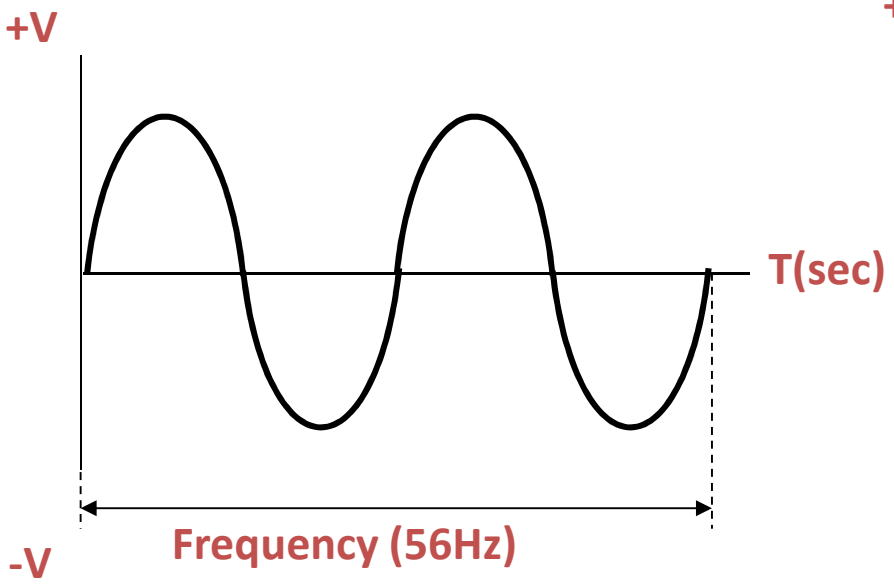
Variable Frequency Output to Compressor Motor

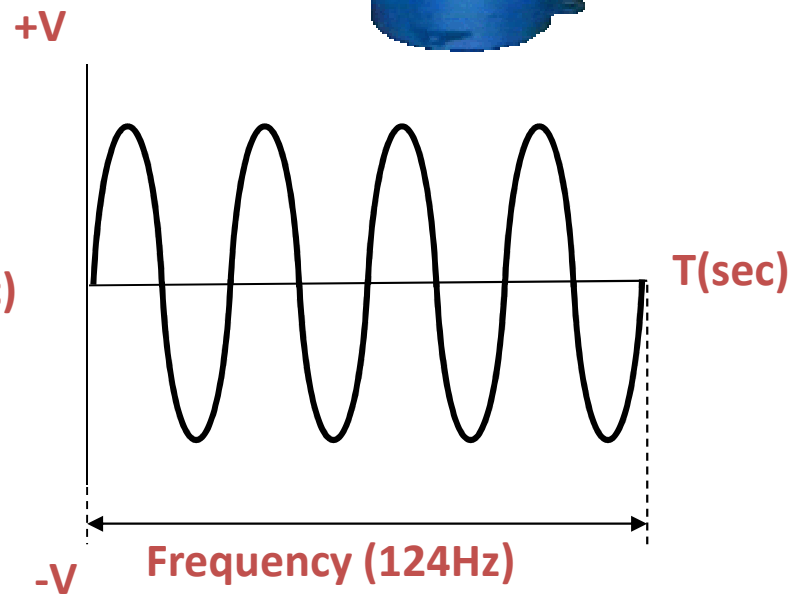


Inverter Scroll Compressor

- 30 to 40% Efficiency Improvement
- Soft-starts with no electrical inrush
- Longer life due to soft-starts

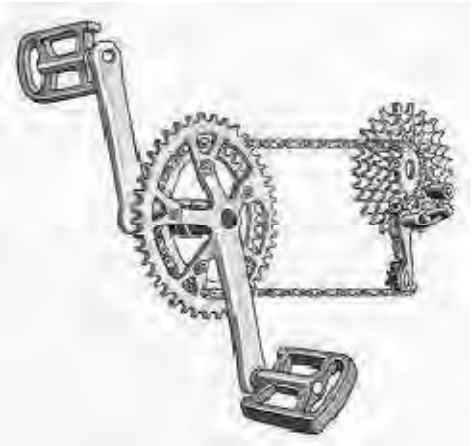






Inverter Drive

15 Hz
Low Part Load



125Hz
Peak Load

Conventional Comfort

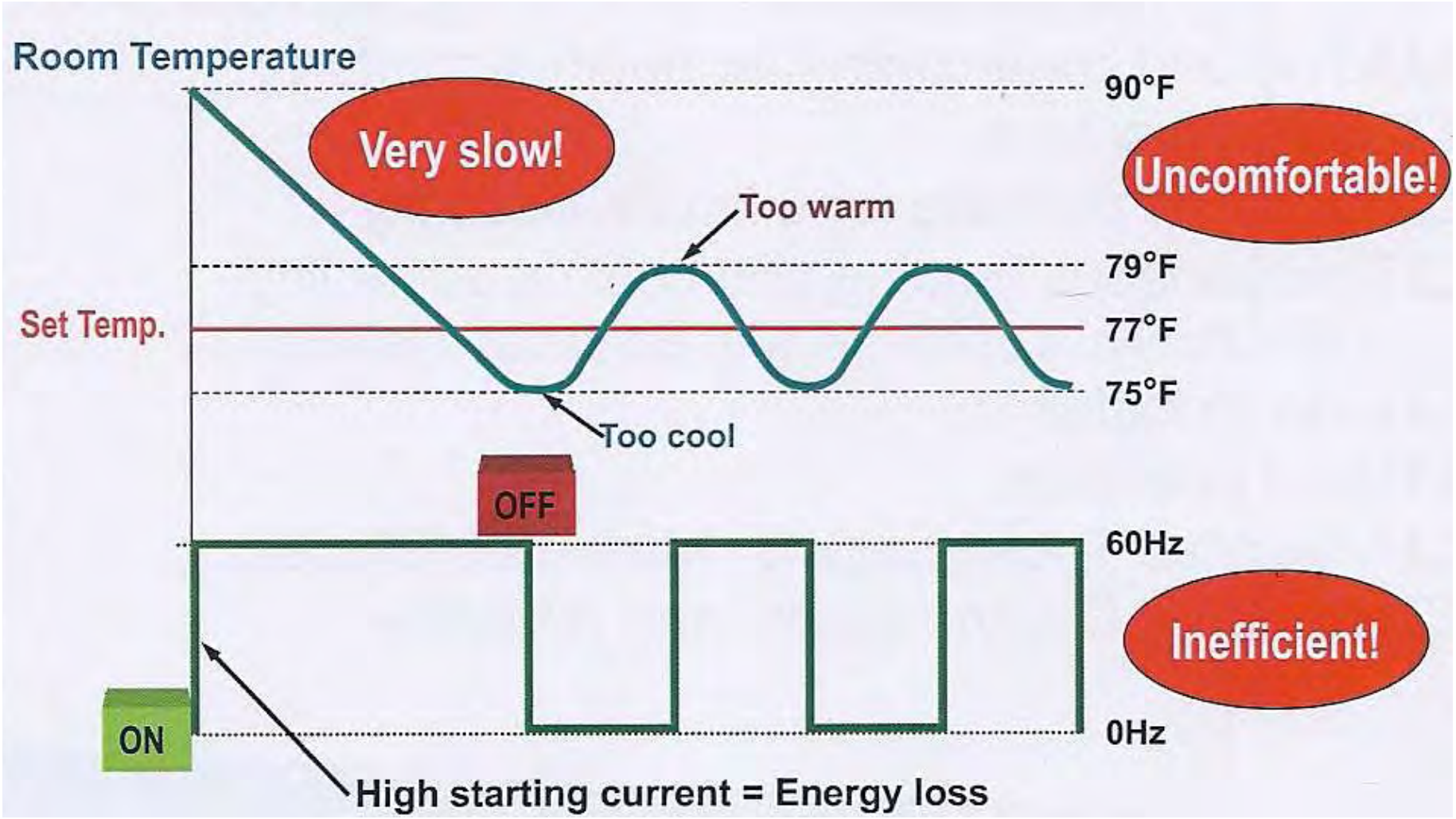


Image Source: Mitsubishi Electronics

VRF Comfort

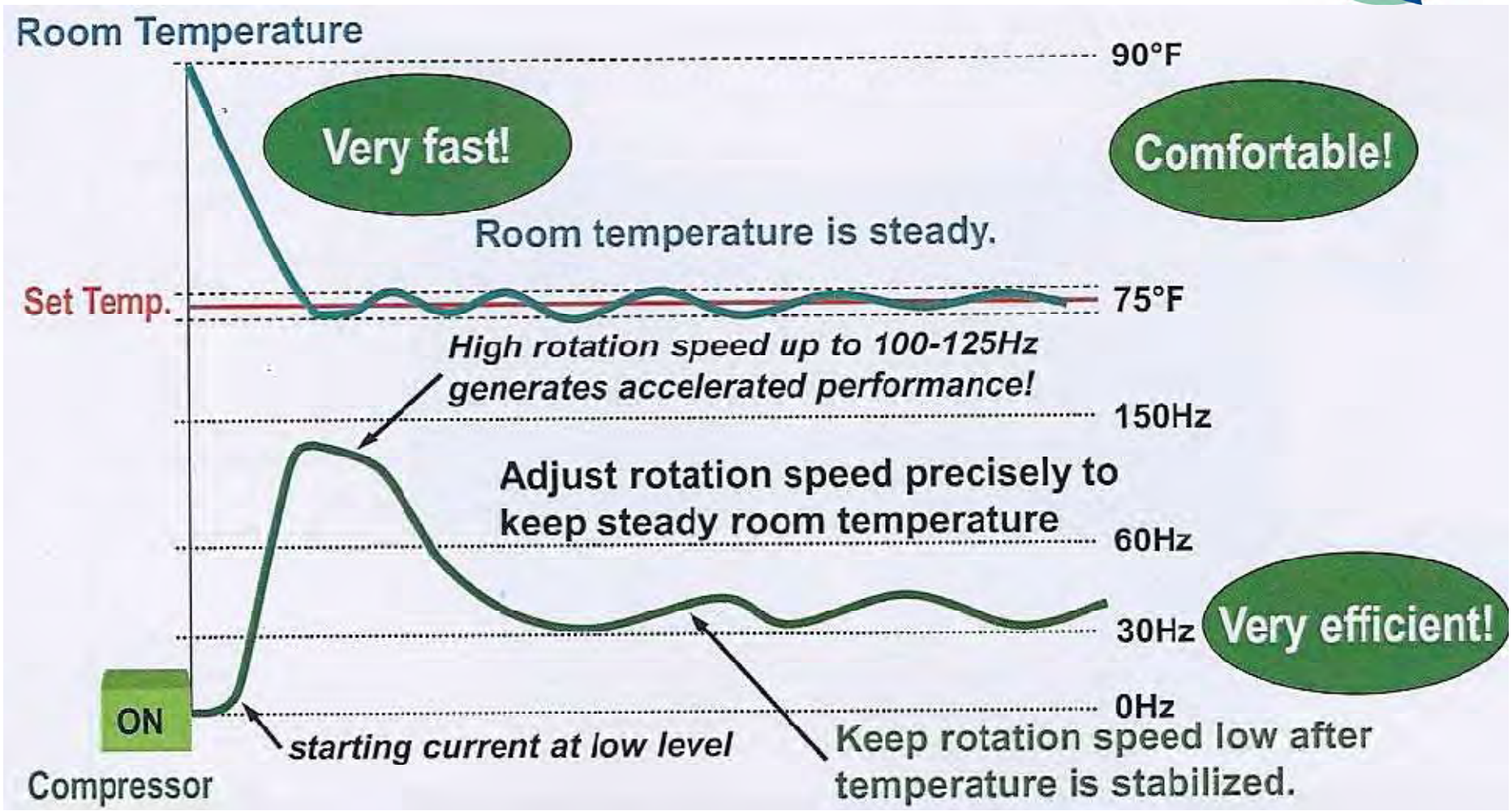
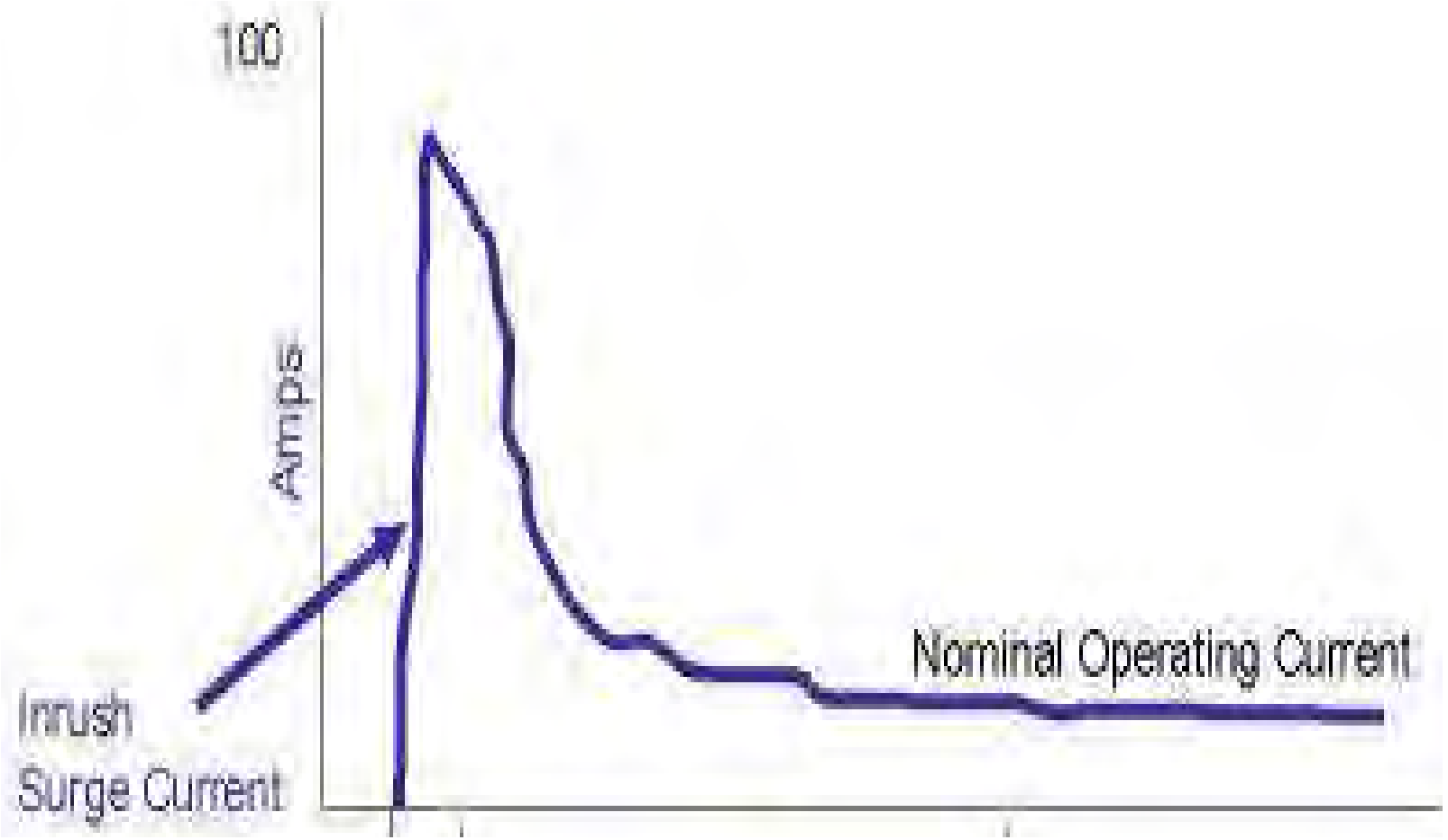
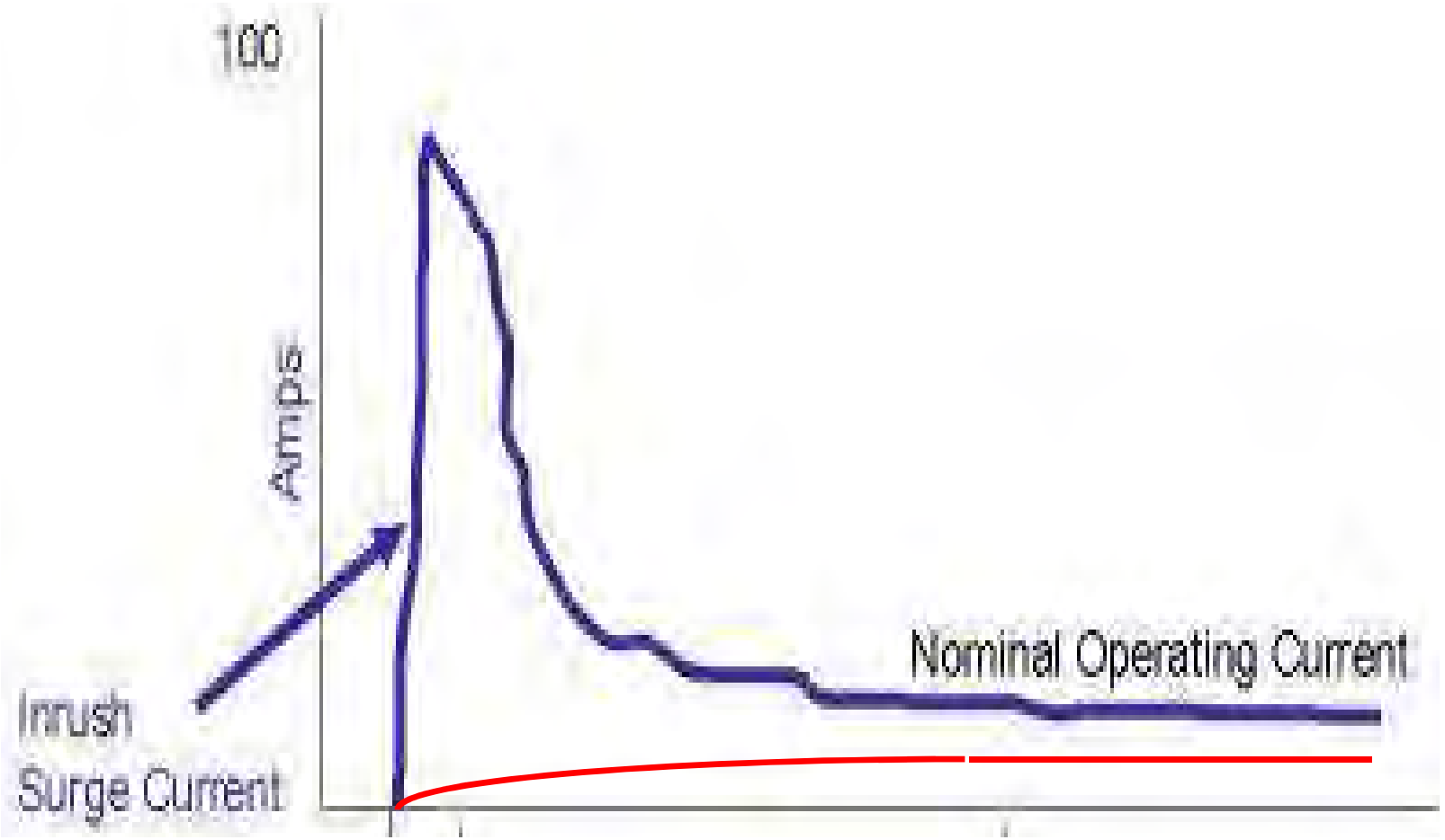


Image Source: Mitsubishi Electronics

Compressor Motor Current

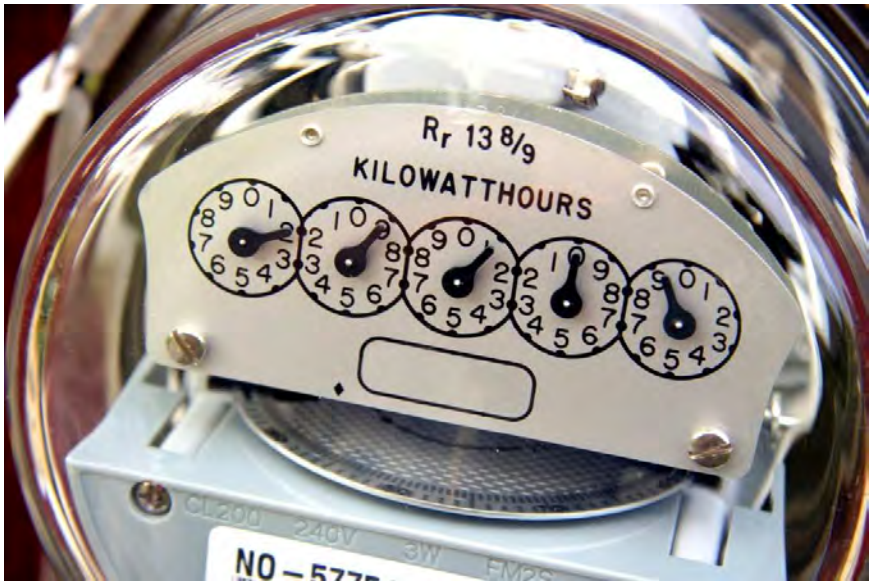


Compressor Motor Current



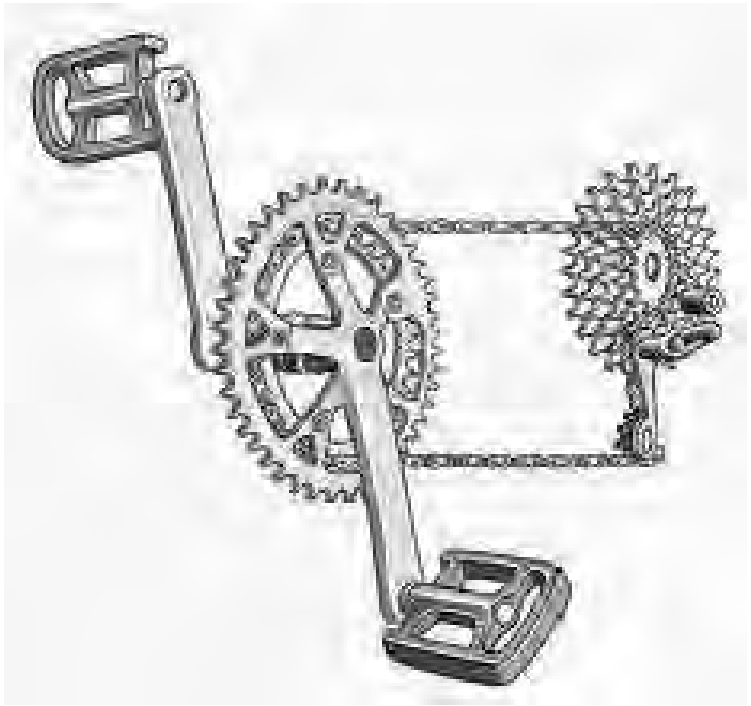
Operating Currents

	Indoor Unit (A)	Outdoor Unit (A)
Conventional	3 - 12	20 - 100
VRFZ	0.15 - 6	2-25



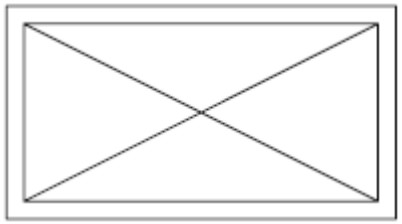
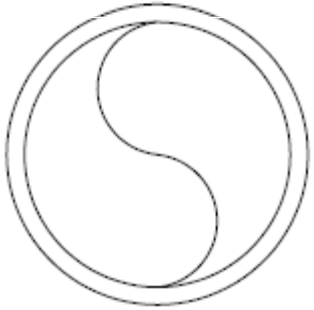
Recap: Inverter Benefits

- Precise control & stability of indoor conditions
- Low starting currents
- Long run times
- Reduces compressor cycling
- Improved durability/longevity
- Variable capacity operation
- Rapid ramp up to meet load
- Minimum capacity to as low as 4% of rated



VRF Space Savings

Space Required to
Deliver 20 tons of Cooling

Rectangular Ductwork (DX System)		**40” x 20”**
Round Ductwork (DX System)		**30” Round**
Piping (4 -Pipe System)		**3” CHWS&R, 3” HWS&R**
Piping (VRF)		**1 3/8” Gas 1 1/8” Liquid**

Quiet Operation

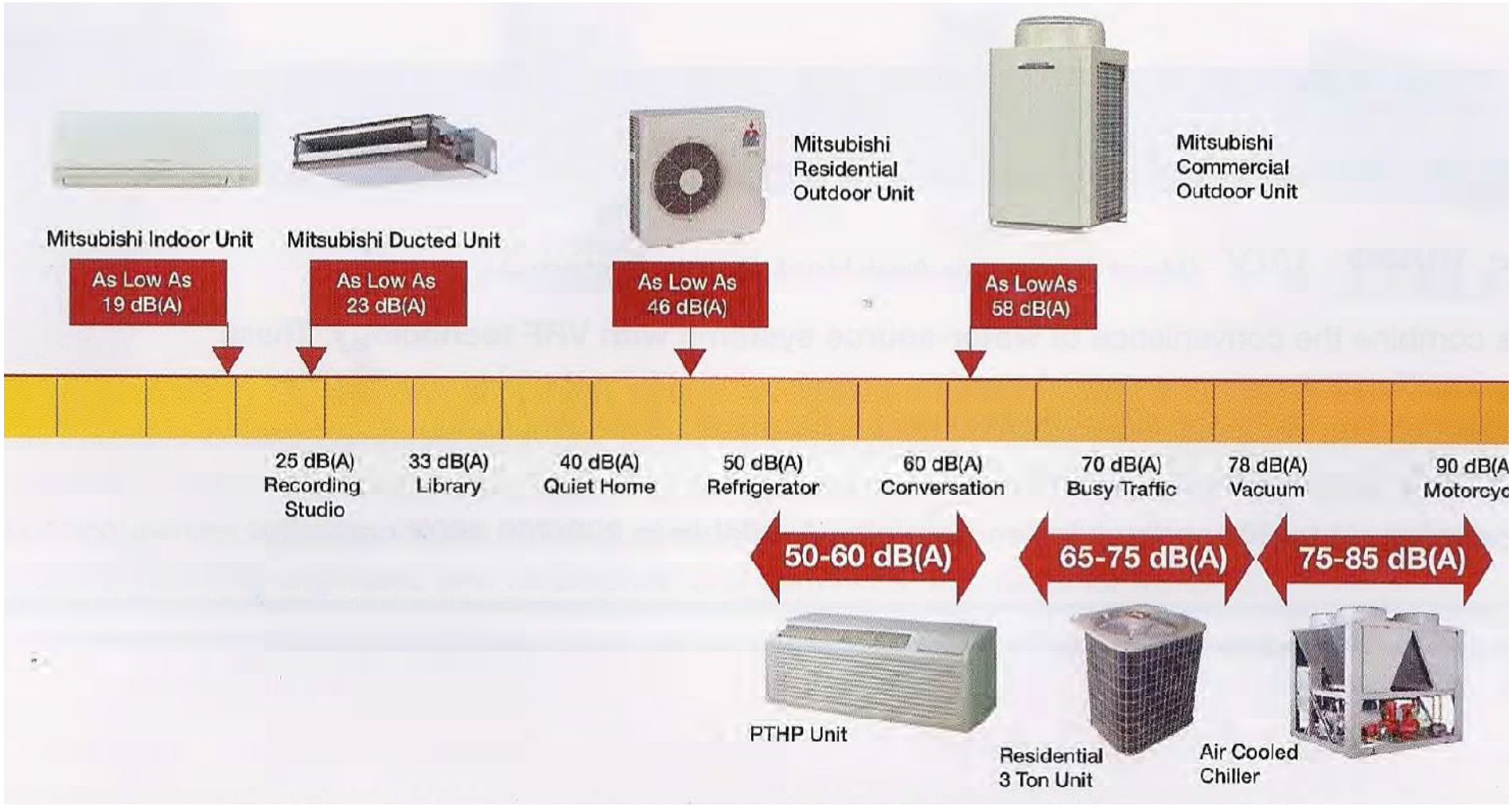
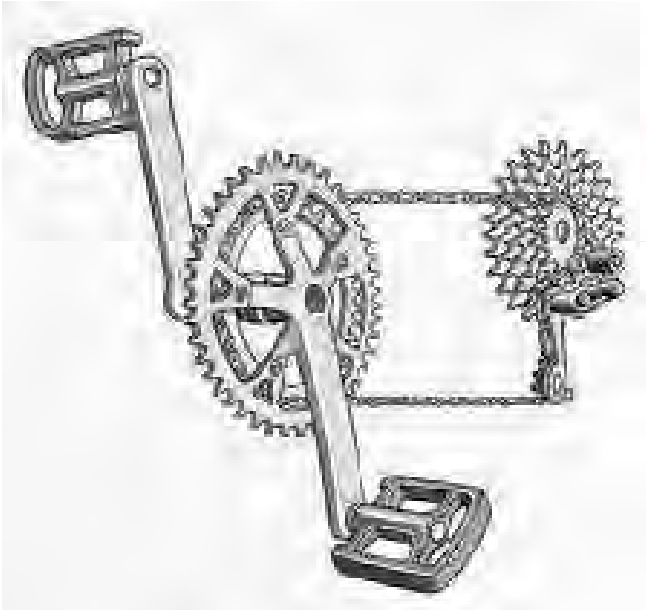


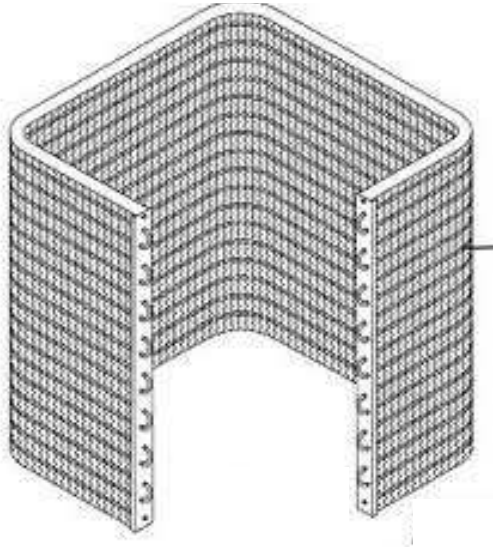
Image Source: Mitsubishi Electronics

VRF & Energy Modeling

- Energy Plus
- EnergyPro
- Others using DOE2.1 engine

VRF, Inverter-Drive & Beyond





Pricing Comparison

k$/Ton	$1.5	$2.0	$2.5	$3.0	$3.5	$4.0	$4.5	$5.0	$5.5	$6.0	$6.5	$7.0	$7.5	$8.0	$8.5	$9.0	$9.5	$10.0
Base																		
Mid-Range																		
Top-End																		
VRFZ																		
GSHP																		

*GSHP pricing does not include 30% Federal tax credit

Summary

VRF Benefits

- Efficient part-load performance
- Versatility
- Comfort/control
- Multiple independent indoor zones
- Quiet operation
- Improved latent control & filtration w/ longer run times
- Reduced need for ductwork & associated duct losses/impacts
- Easy of installation
- Many units are ventilation compatible
- High reliability/low maintenance

VRF Issues & Concerns

- Market Inertia
- Lack of 3rd party performance data
- Inappropriate industry rating metrics
- Cost
- Installer/Service training & skills
- Complexity
- Power sensitivity
- Supplemental heating integration
- Filtration concerns
- Costly to service/cleaning condenser coils
- Lack of control based on latent (most units)
- Need for supplement dehumidification at low loads

Thank You